ALD Overview

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RHIC S&T Review
16-18 September 2014

BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

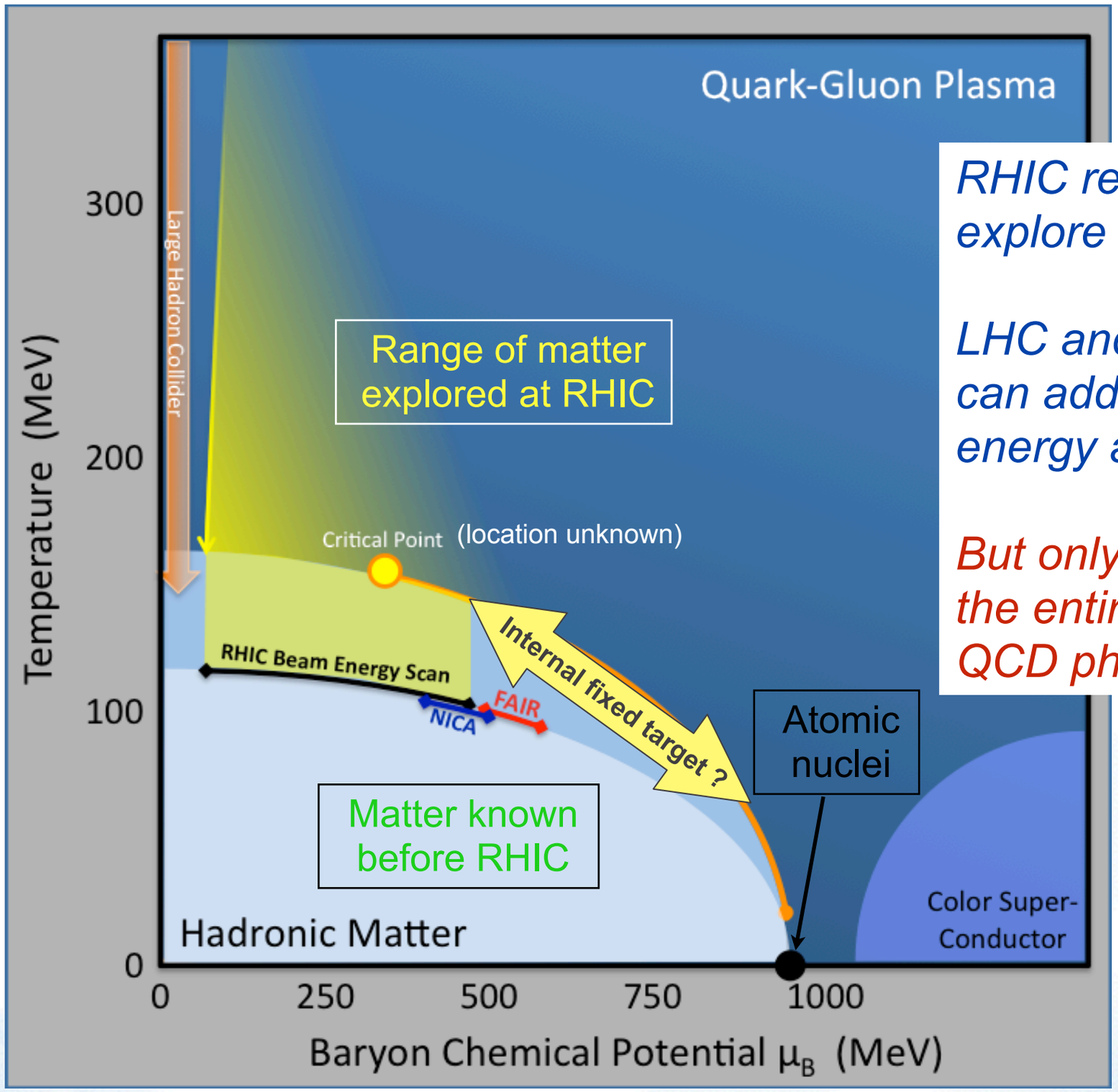
Office of Science
U.S. DEPARTMENT OF ENERGY

Outline

- FY12-14 facility highlights
- FY12-14 science highlights
- Priorities and run plans 2015-22
- Status of sPHENIX project
- Long-term vision and transition to eRHIC
- Realignment of collaborations
- Laboratory support
- Synergies with Work for Others
- Response to recommendations from recent S&T and operations reviews

2012-14 Facility Highlights

The Landscape



RHIC remains the premier facility to explore the phases of QCD matter.

LHC and, in the future, FAIR & NICA can add exciting capabilities at high energy and high baryon density.

But only RHIC can cover essentially the entire accessible region along the QCD phase boundary.

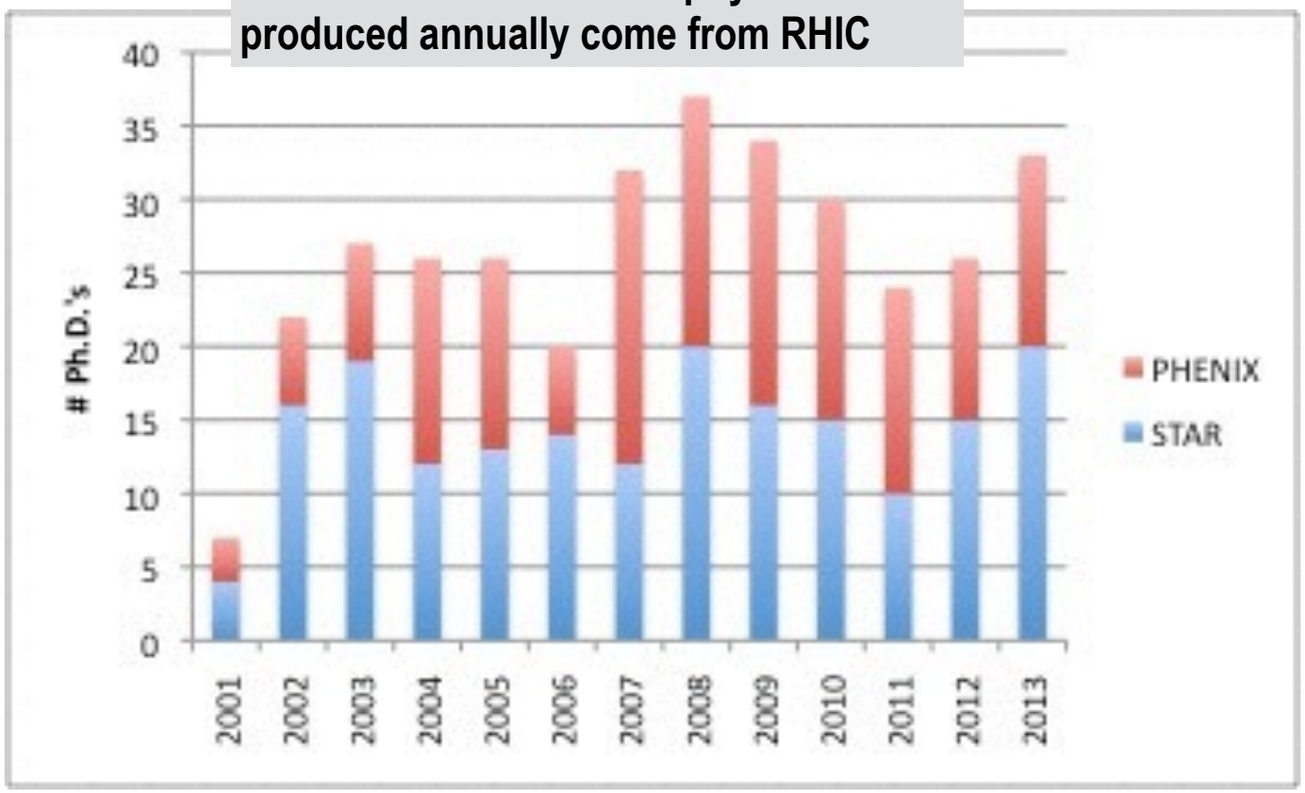
Main Discoveries

- Hot nuclear matter produced in collisions at RHIC/LHC is a strongly coupled nearly "**perfect**" **liquid** quark-gluon plasma. RHIC's QGP is (on average) *closer to perfection* than the QGP produced at LHC. The QGP is made up of individually flowing quarks, not quarks bound into baryons and mesons.
- Energetic quarks and gluons moving through the QGP rapidly lose energy, causing jets to be strongly **quenched**.
- Light quarks (*u,d,s*) are completely **thermalized** in the QGP; these quarks recombine during hadronization.
- Heavy quark bound states (J/ψ, ϒ') **melt** in the QGP due to color screening and ionization, but can re-form when the QGP hadronizes.
- Experiments with colliding polarized protons at RHIC have shown that **gluons contribute** a sizable fraction, possibly half, **to the proton's spin.**

RHIC: Productivity and Impact

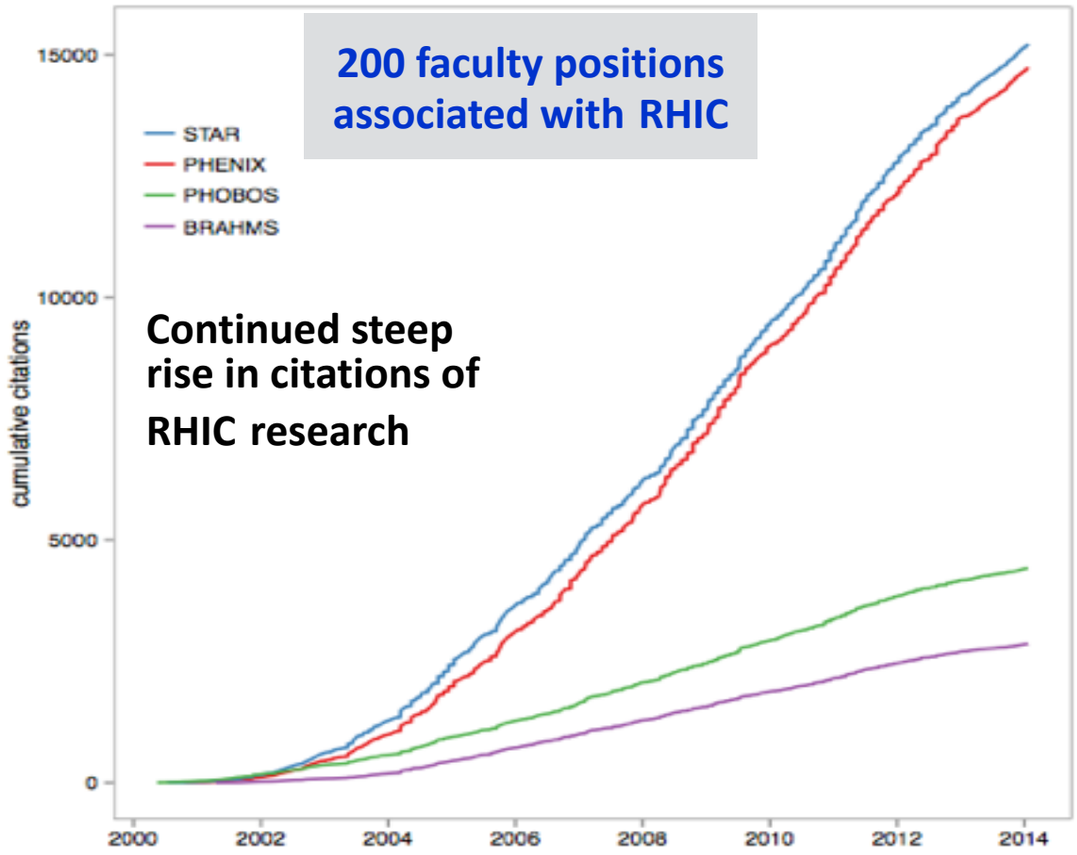
Collaboration	Total # Refereed Papers	Total # Citations for Refereed Papers	# PRL's	# Citations for 2005 White Paper	Position Among Most Cited NP Papers 2001-12	# Papers with >250 Citations
PHENIX	129	15,889	63	1,679	5	15
STAR	155	16,571	57	1,723	4	16
PHOBOS	39	4,363	15	1,280	7	1
BRAHMS	22	2,860	10	1,261	8	3
Total	**345**	**39,683**	**142**	**5,943**	**4 in top 10**	**33**

About 30-40% of nuclear physics PHD's produced annually come from RHIC

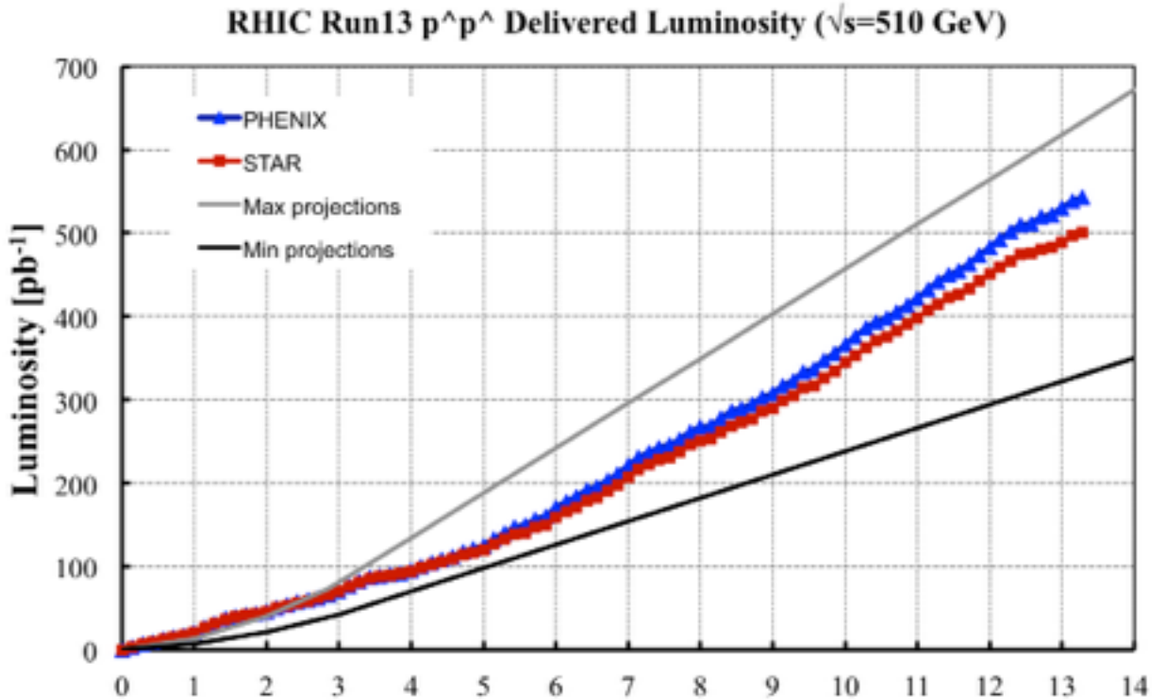


200 faculty positions associated with RHIC

Continued steep rise in citations of RHIC research



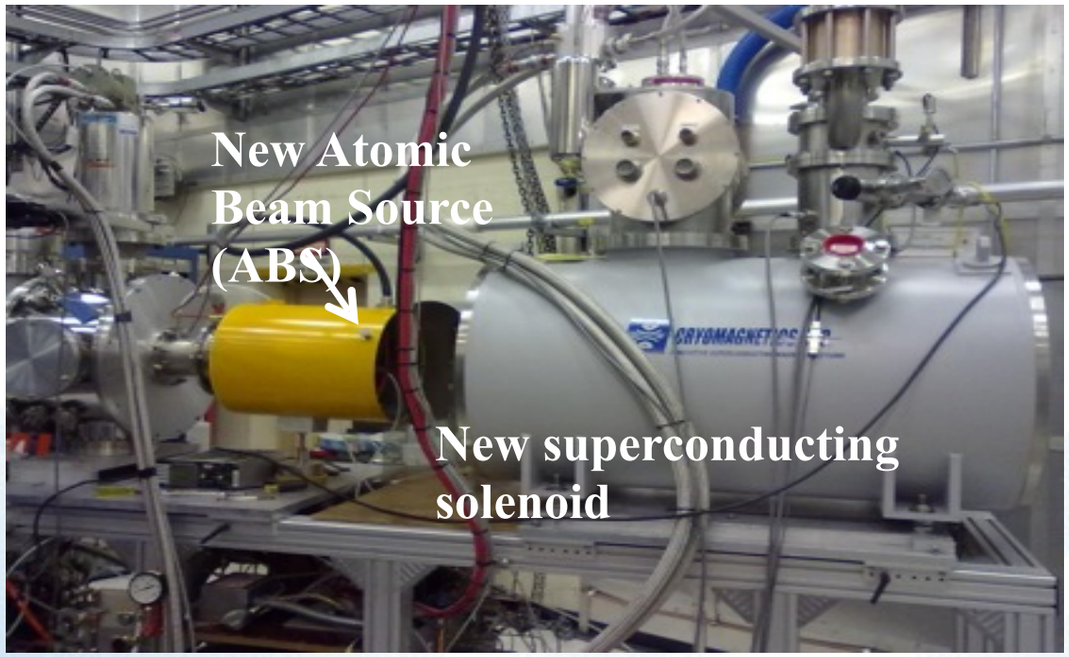
RHIC Run 13



RHIC II p↑+p↑ performance

p↑+p↑ luminosity from Run-13 exceeds all previous p↑+p↑ runs combined

new polarized source

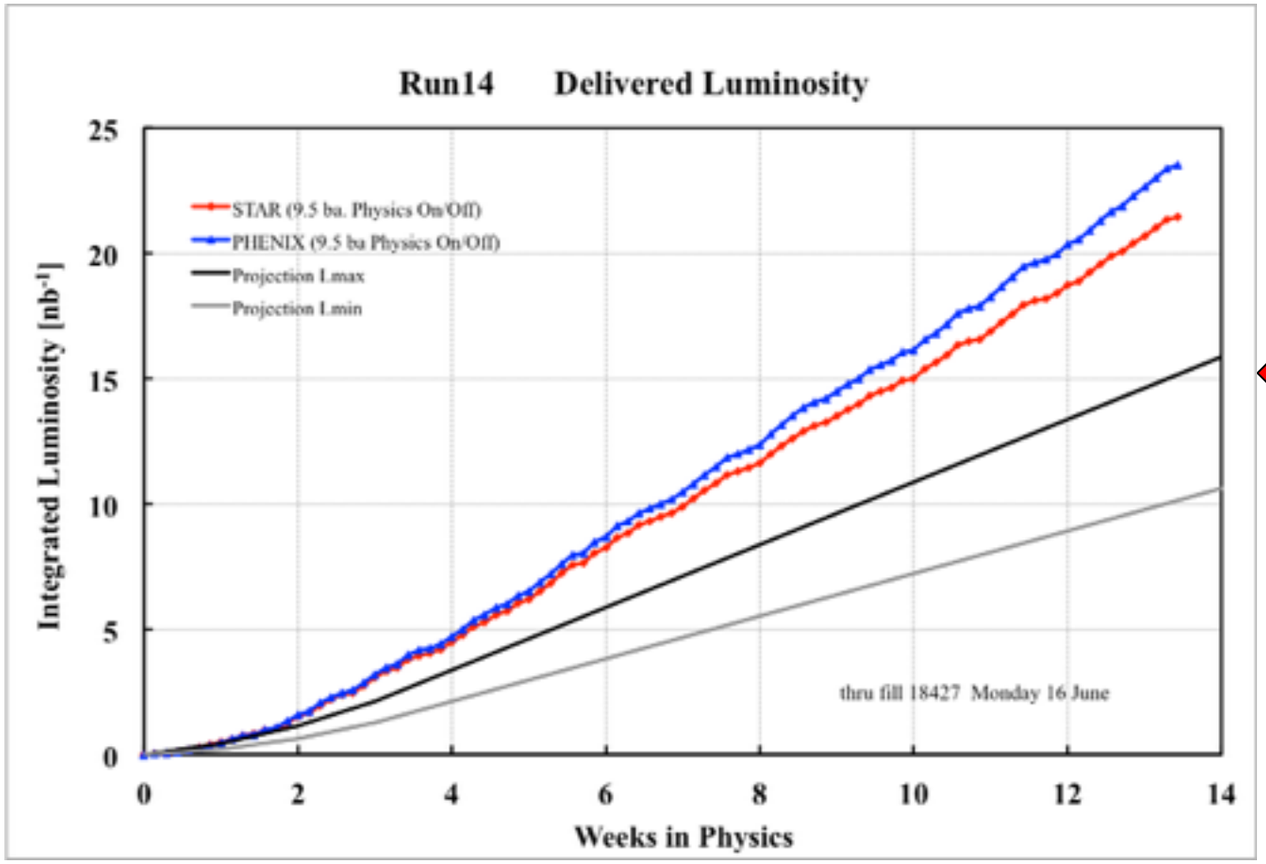


stores with highest average pol.

H-jet measured polarization
(average over intensity, time, 14 best stores)

	Run-12	Run-13
Blue	*52.0%*	*57.0%*
Yellow	*58.2%*	*57.7%*

RHIC Run 14

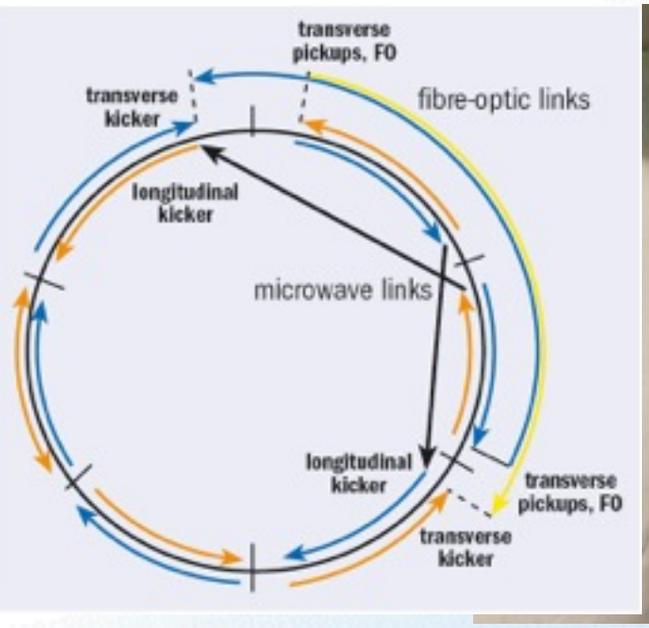


RHIC II Au+Au performance

Au+Au integrated luminosity from Run-14 exceeds all previous Au+Au runs combined

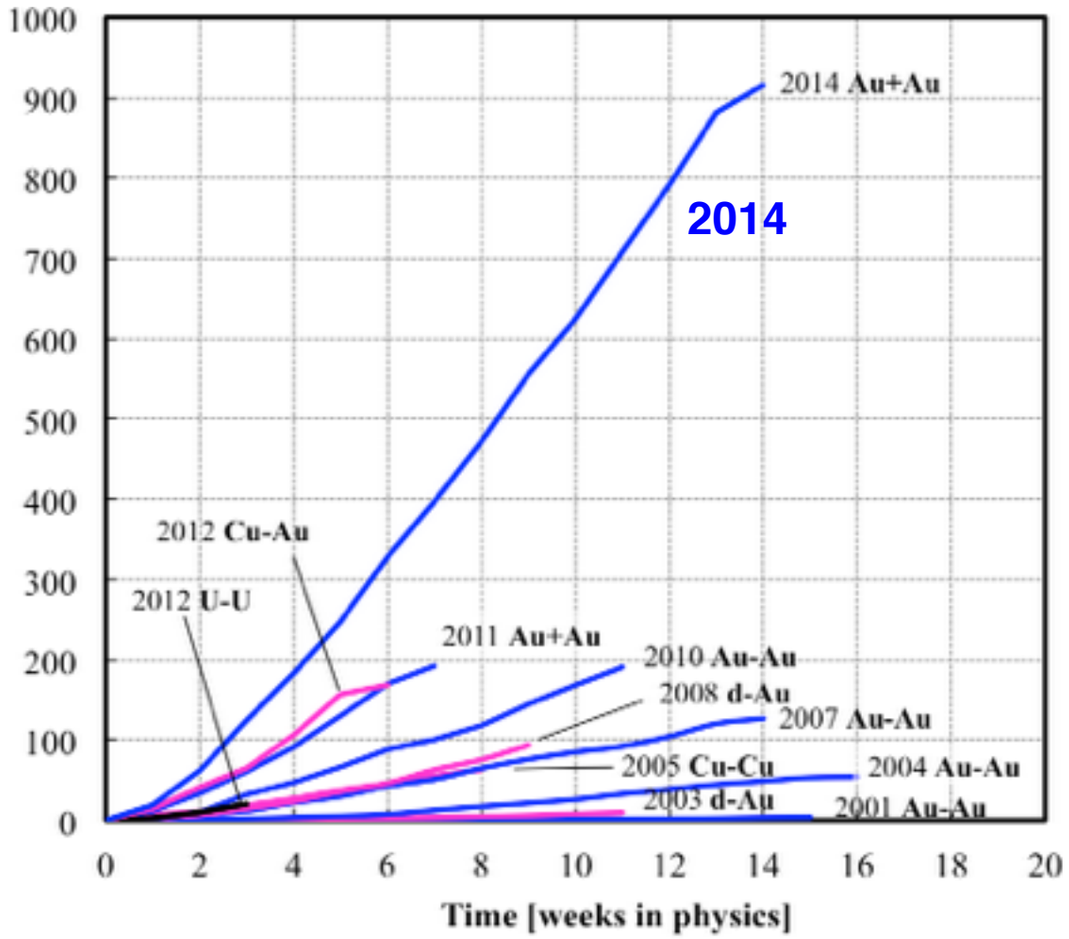
Electron Beam Ion Source

3D stochastic cooling

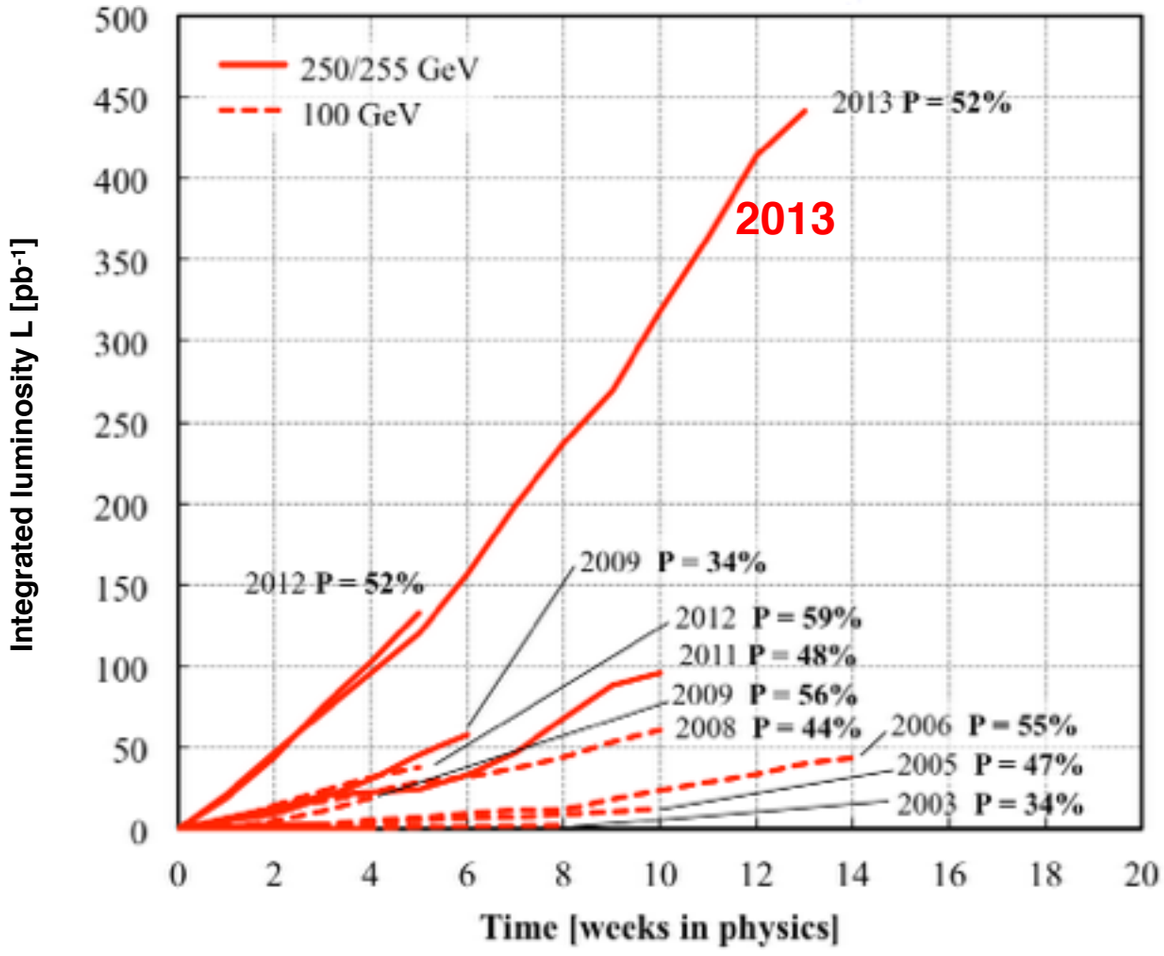


RHIC-II Performance

Heavy ion runs



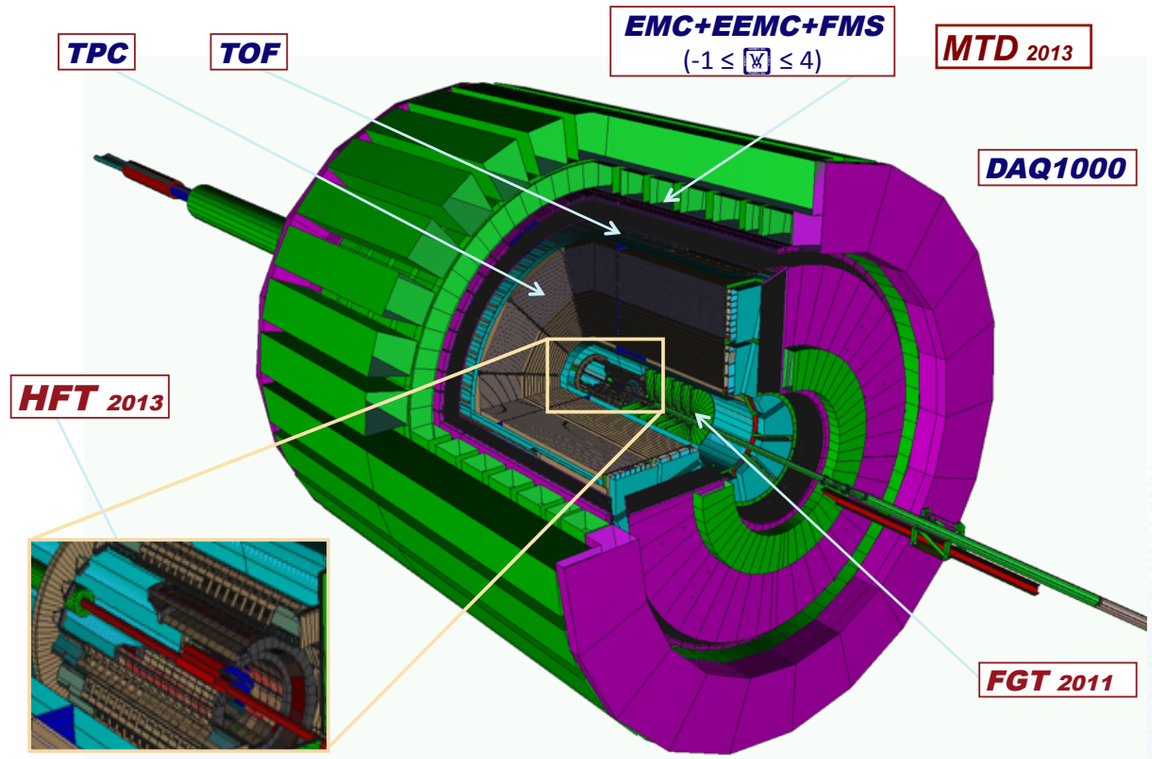
Polarized proton runs



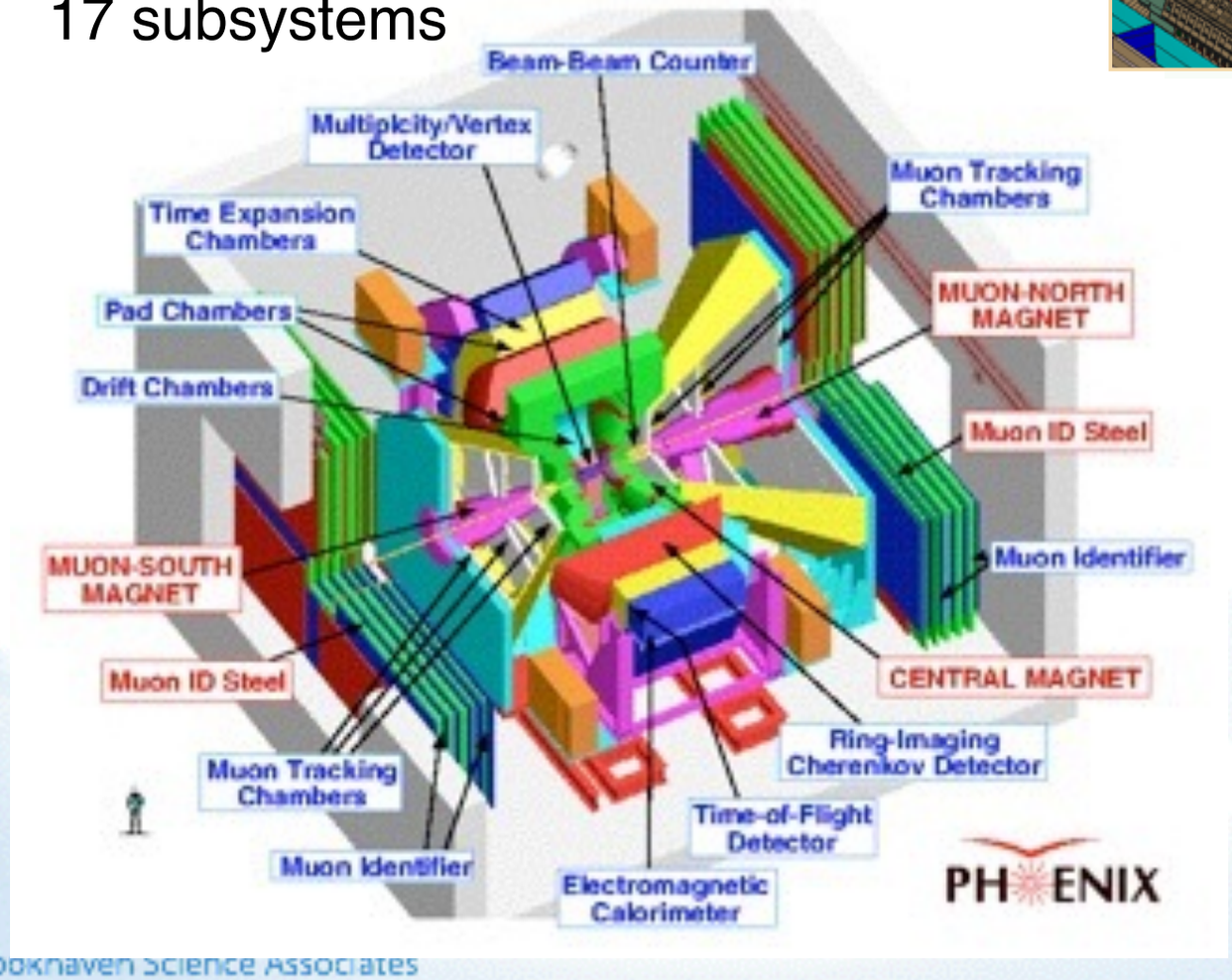
Dramatic increase in performance of RHIC as a result of 3-D stochastic cooling, new high intensity ion source (EBIS), and other improvements (beam-beam compensation, IR compression, etc.).

RHIC Detectors

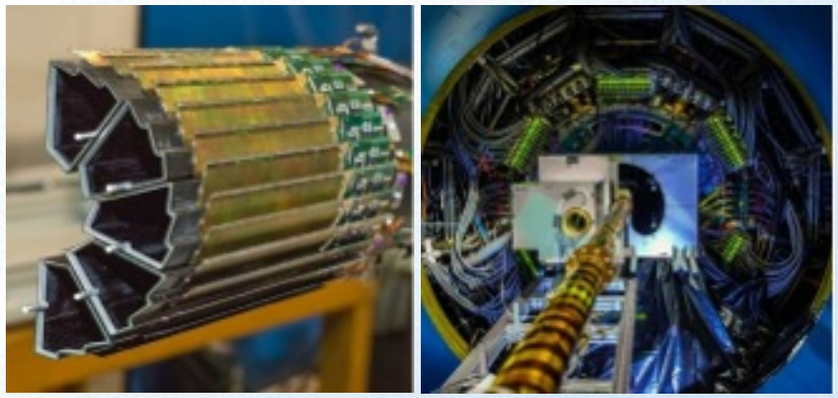
STAR Detector



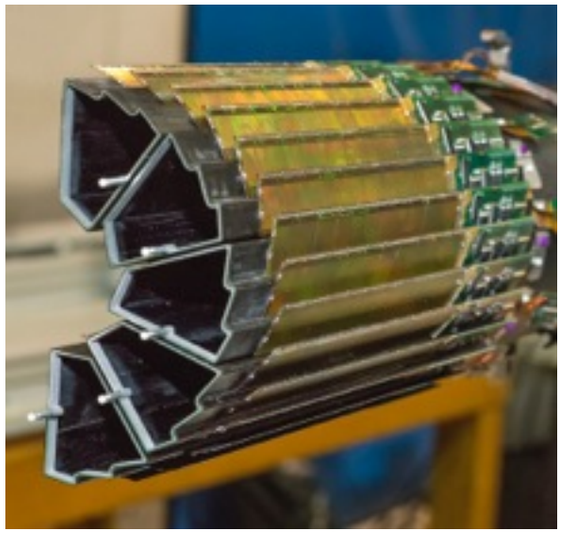
17 subsystems



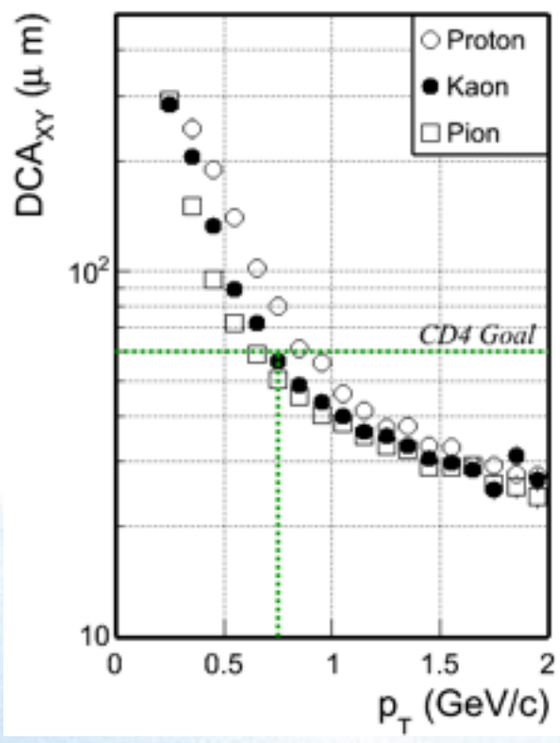
NEW: Heavy Flavor Tracker

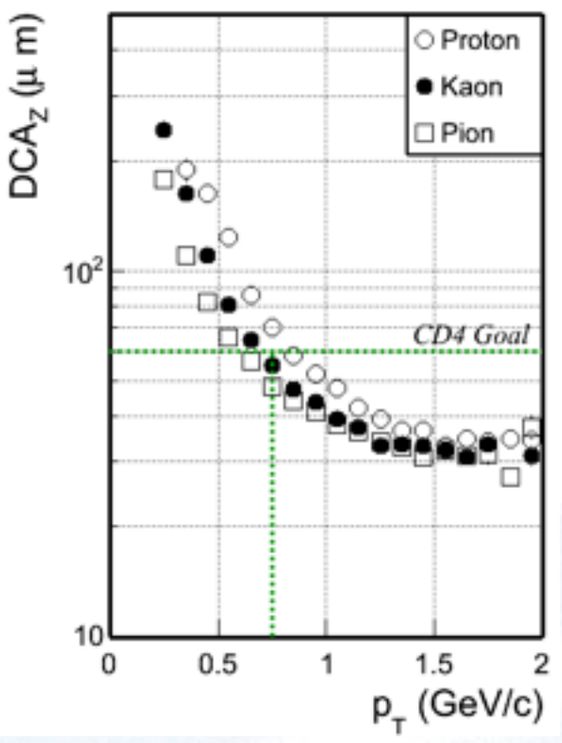


STAR: HFT



$\sqrt{s_{NN}}$ = 200GeV Au+Au Collisions





Heavy Flavor Tracker (HFT)
Full reconstruction of charm hadrons with displaced vertex

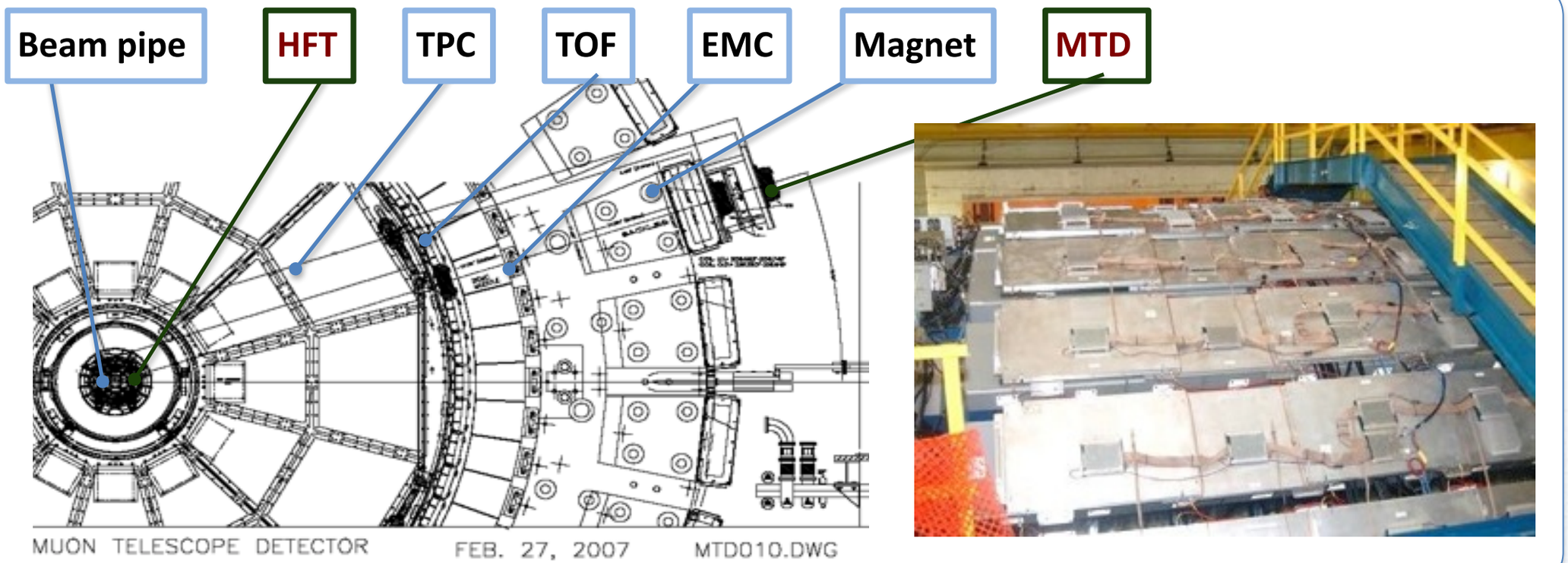
Physics goal:
Precision measurement of heavy quark hadron production in heavy ion collisions

All 3 sub-detectors (PXL, IST, SSD) were completed, installed prior to Run14

PXL – heart of the HFT: state-of-art detector, MAPS technology, first time used at a collider experiment.

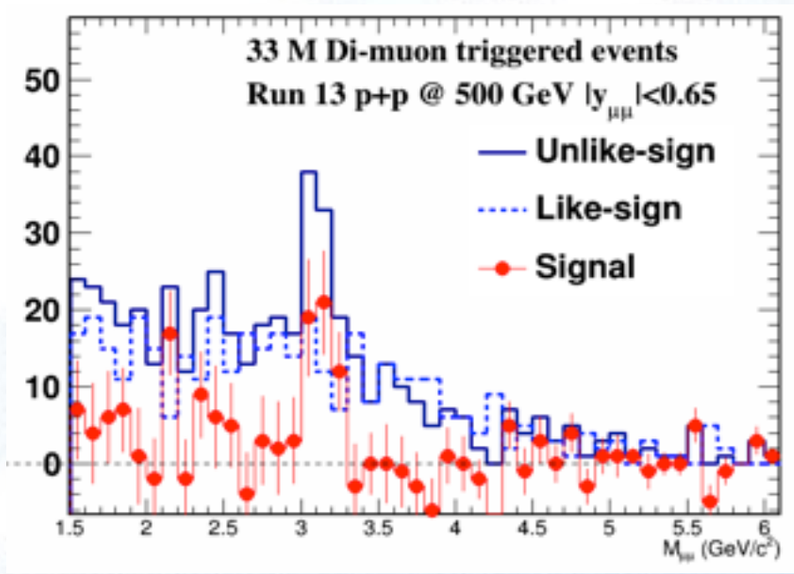
Reached Performance Requirement Goal:
With survey and preliminary alignment,
Kaons at 750 MeV/c: DCA < 60μm

STAR: MTD

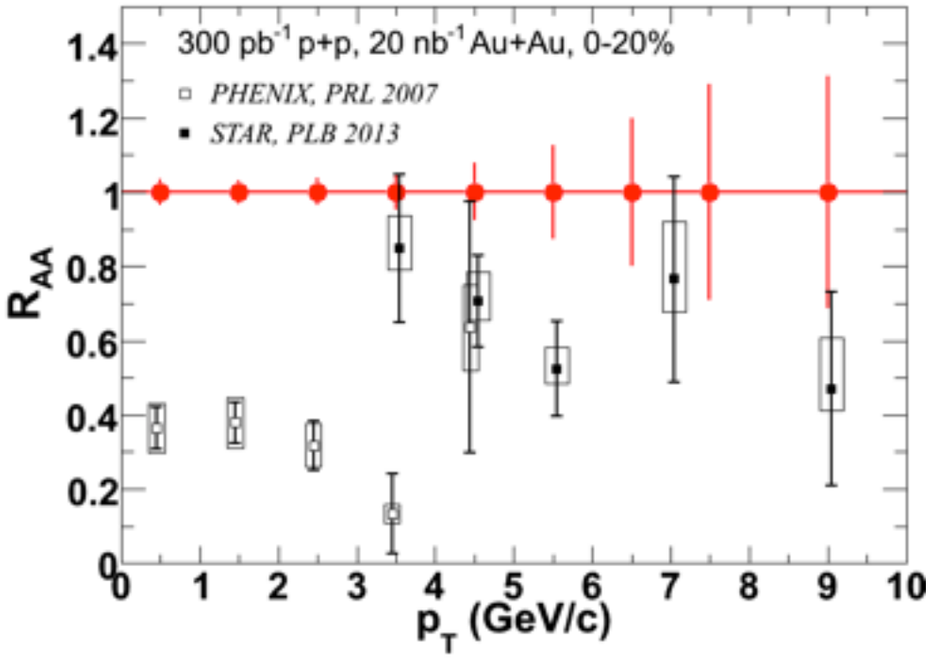


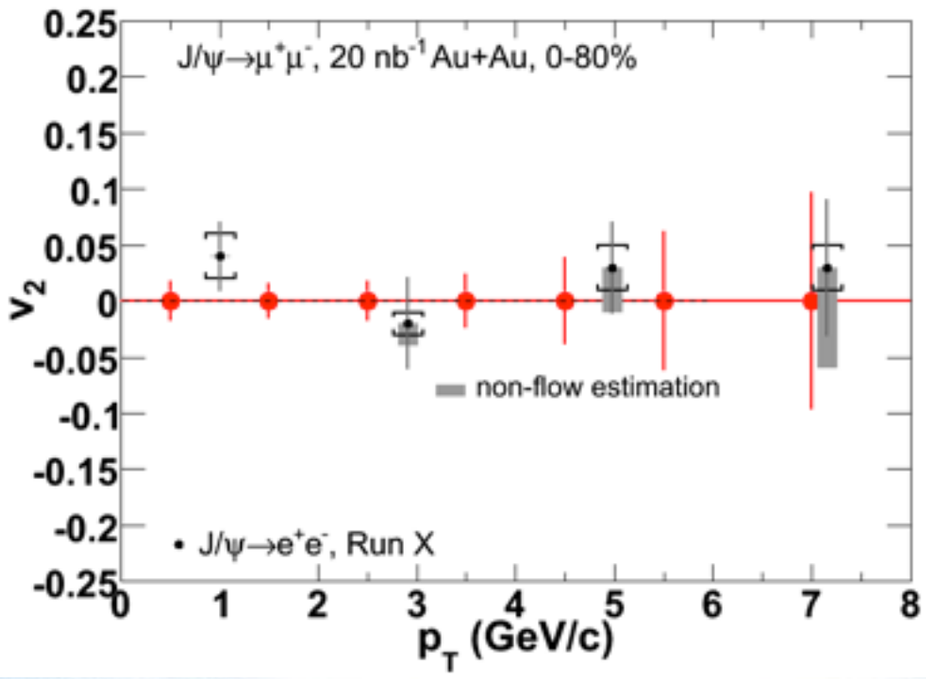
Muon Telescope Detector (MTD):

1) Physics goal: **Heavy Quarkonia**
2) MRPC technology; covers ~45% azimuthally and $|y| < 0.5$
3) Fully installed in Run14: sampling 10 nb^{-1} in 200 GeV Au+Au for quarkonium physics



MTD: Quarkonia





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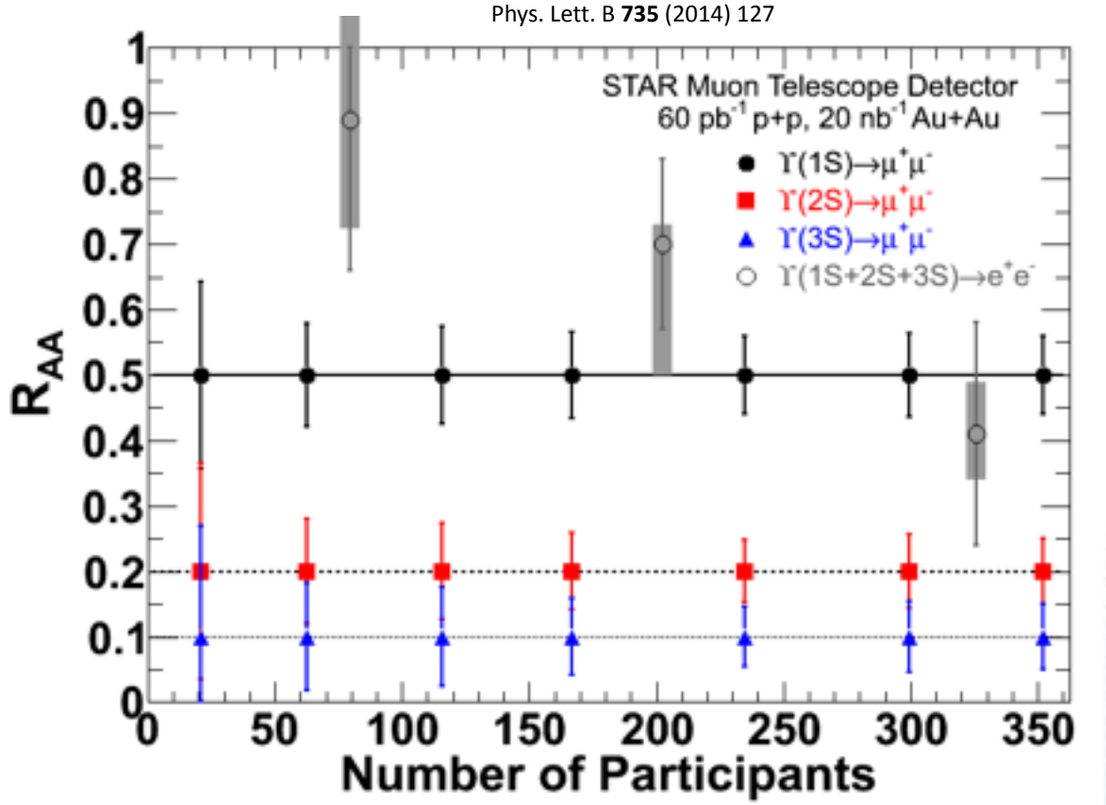
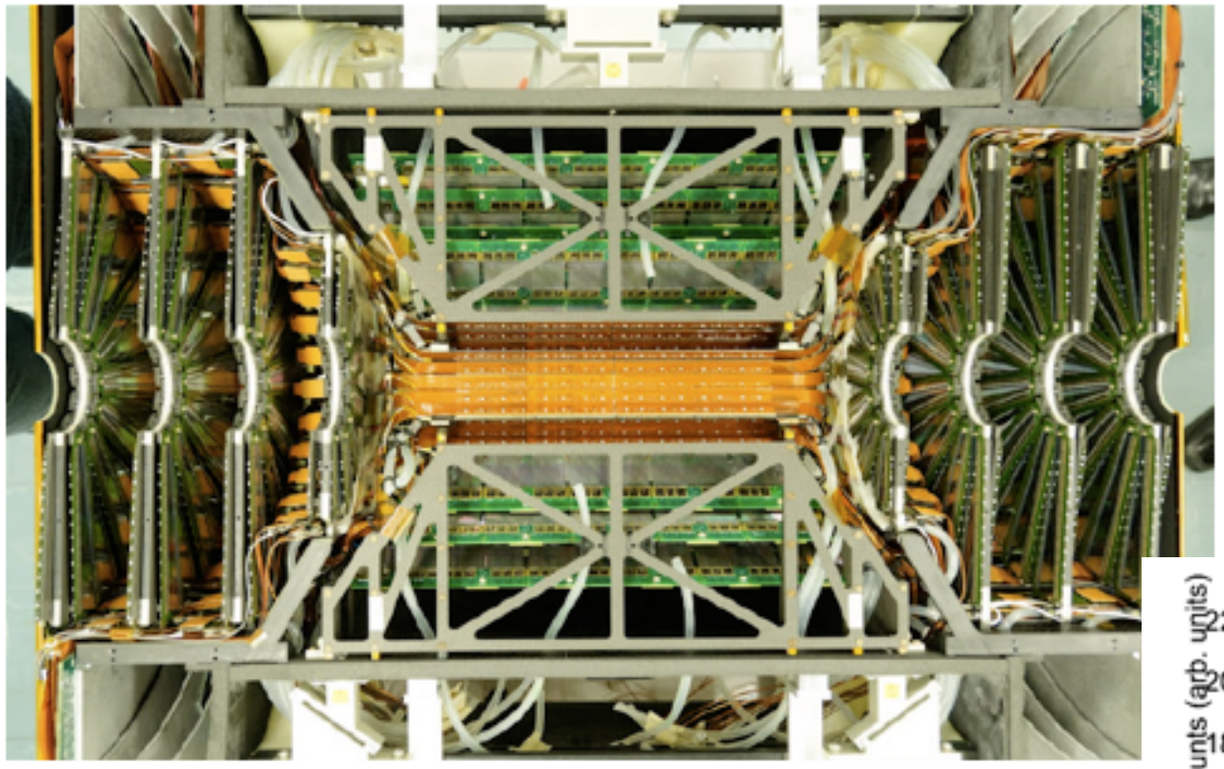


MTD: Improves statistical uncertainty
as well as systematic uncertainty;
separates Upsilon states

MTD+HFT: B→J/ψ, J/ψ-D …

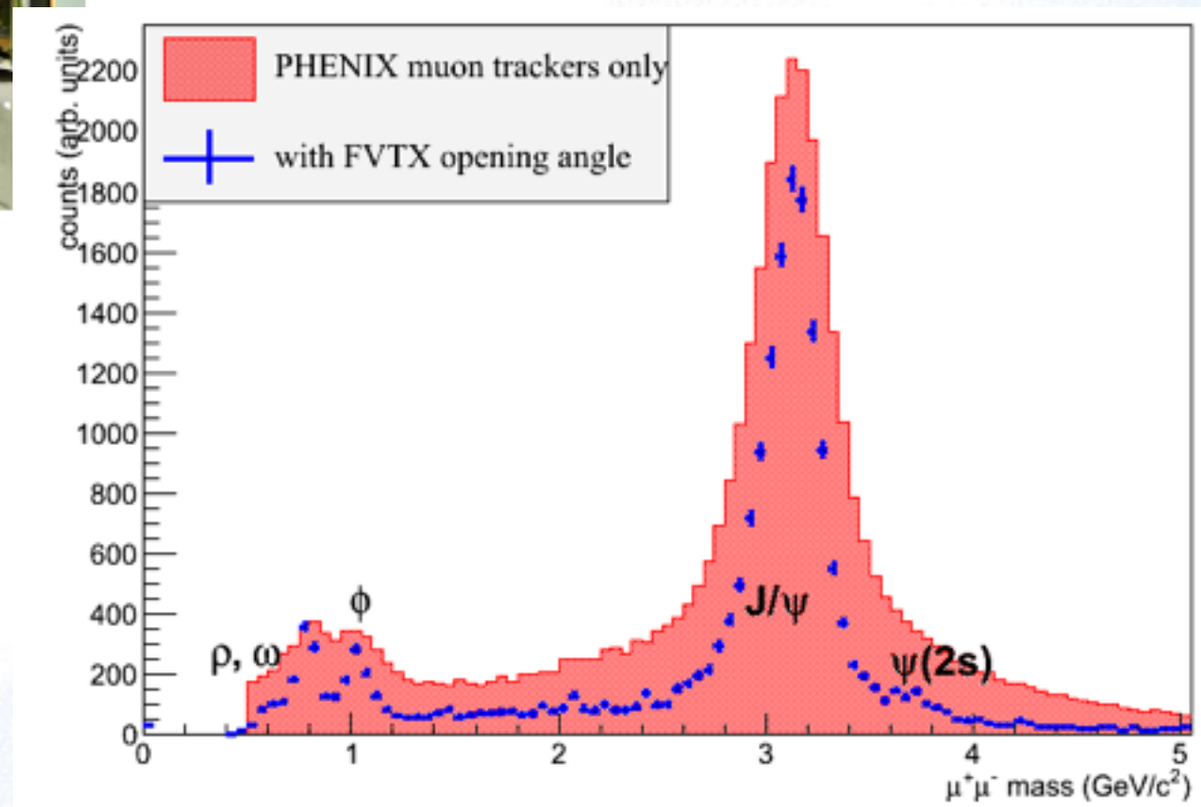
PHENIX: FVTX



Installation of FVTX in December 2011

Performance of FVTX in Run 13:

Greatly improved J/ψ→μμ mass resolution; reduced combinatorial background



2012-14 Science Highlights

PHENIX accomplishments

A+A

- I_{AA} for γ-hadron correlations in Au+Au
- Cu+Au v_1 and v_2 vs p_T
- J/ψ R_{AA} in Au+Au, Cu+Au and U+U
- Measurement of Υ(1S+2S+3S) R_{AA} in Au+Au
- Au+Au 3D HBT vs √s show expansion slowing near 30 GeV
- Direct photon v_2 in Au+Au confirmed
- First measurement of direct photon v_3 in Au+Au

d+Au

- Forward di-hadron suppression in d+Au
- Suppression of ψ' relative to J/ψ in d+Au vs N_{coll}
- R_{dAu} of π^0, η, and jets in peripheral and central events
- Measurement of v_2 in d+Au
- Mass splitting of d+Au v_2 vs p_T

- Competitive measurement of dark photon limit

p+p

- A_{LL} for π^0, η contributing to $\Delta G > 0$

STAR accomplishments

High-Energy Collisions,

- First Direct D^0 reconstruction
  (radial flow and charm energy loss)
- Quarkonia (J/ψ, Υ) R_{AA}, J/ψ v_2
  (Disassociation and coalescence)
- Initial Geometry U+U (v_2 vs multiplicity)
  (gluon saturation and initial condition)
- γ-hadron, first inclusive Jet and jet A_j
  jet quenching, η/s
- Charge Separation wrt reaction plane
  (chiral magnetic effect and QCD topology)
- Dielectron mass spectra and direct virtual γ^*
  (in-medium vector meson)
- Discoveries of anti-hypertriton, anti-^{4}He and attractive Λ–Λ interaction

Beam Energy Scan

- Minimum and double sign change of v_1 slope
  (softening Equation of State)
- Net-proton Kurtosis
  (critical point fluctuation)
- Antiparticle/particle and ϕ v_2 difference
  (Hadronic Interaction, turn-off QGP)
- Low-mass dielectron spectra
  (chiral symmetry and baryon density dependence)
- Charge separation and its energy dependence
  (turn-off QGP signature)
- R_{CP} systematics

Polarized p+p

- Jet A_{LL} ($\Delta G>0$)
- A_N of $W^{\pm}$ Boson (sea quark polarization)
- Interference Fragmentation Function
- Forward A_N vs jettiness

Science highlights

Just a sample!

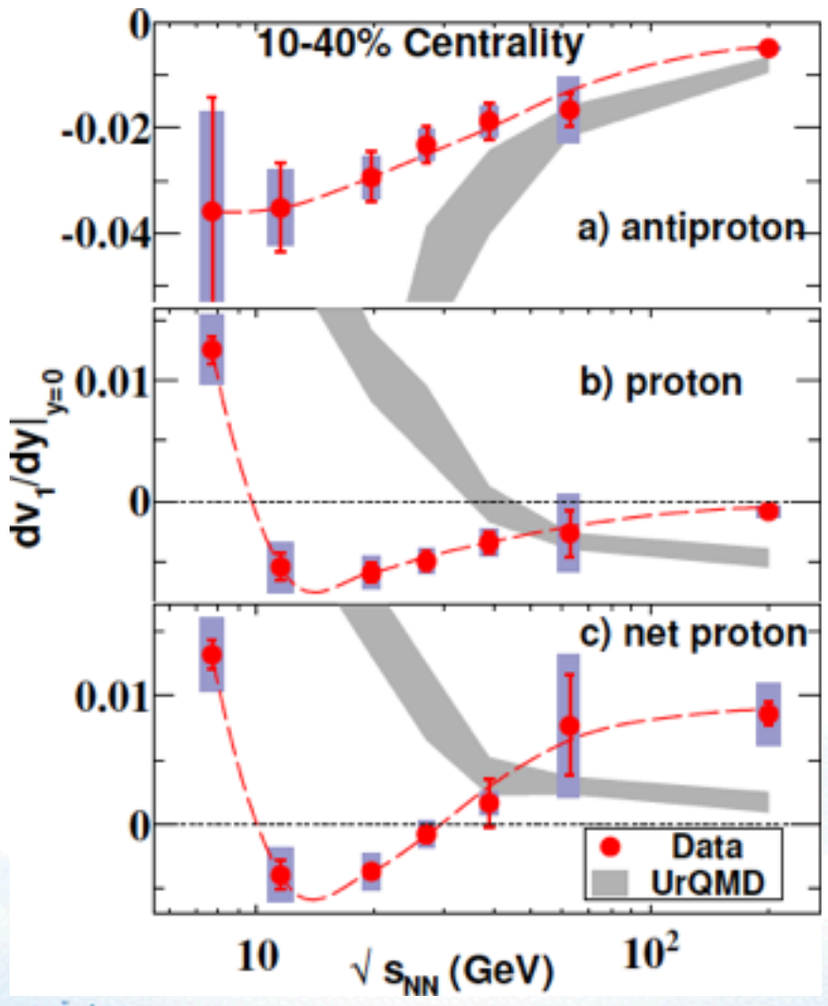
- Beam Energy Scan I
- Identified D^0
- Charmonium and Upsilon
- Perfect Liquid QGP at RHIC vs. LHC
- Versatility of RHIC: U+U
- How small can a QGP be?
- Gluon contribution to proton spin
- $\Lambda\Lambda$ interaction
- Dark photons

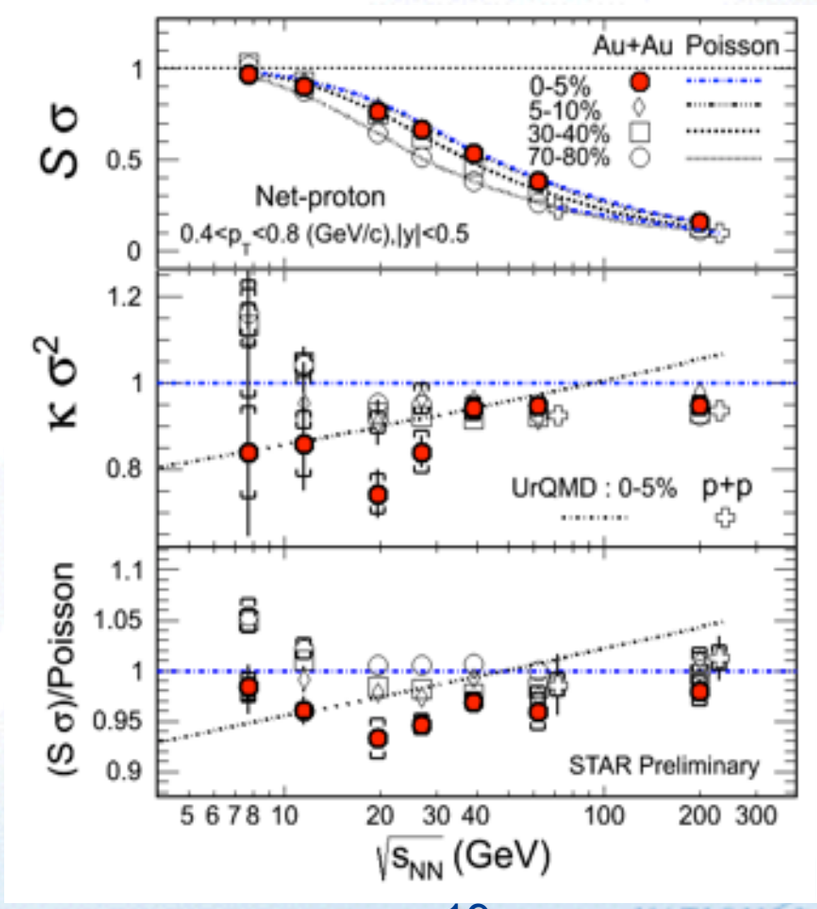
Beam energy scan I

- BES Phase 1 analyses published
- Au+Au Run at 15 GeV in Run 14
- Hints of exciting behavior, but higher luminosity Phase 2 required for definitive results
- BES II White Papers presented to 2014 PAC
- BES Workshop at LBNL

Data taken and analyzed at
$\sqrt{s_{NN}}$ = 39, 27, 19.6, 11.5, 7.7 GeV
Data taken at $\sqrt{s_{NN}}$ = 15 GeV

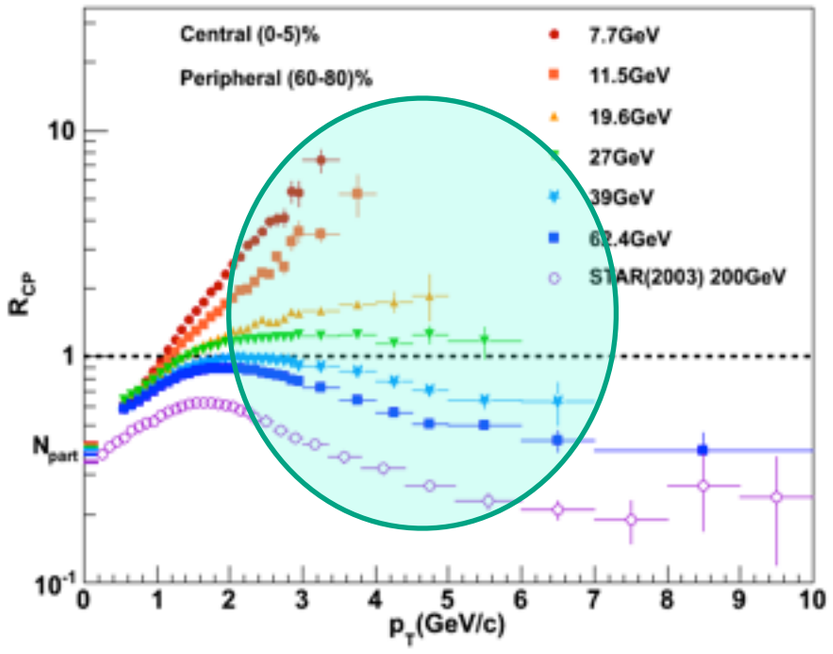
Partonic interaction dominant
at $\sqrt{s_{NN}} \geq$ 39 GeV
Hadronic interaction dominant
at $\sqrt{s_{NN}} \leq$ 11.5 GeV



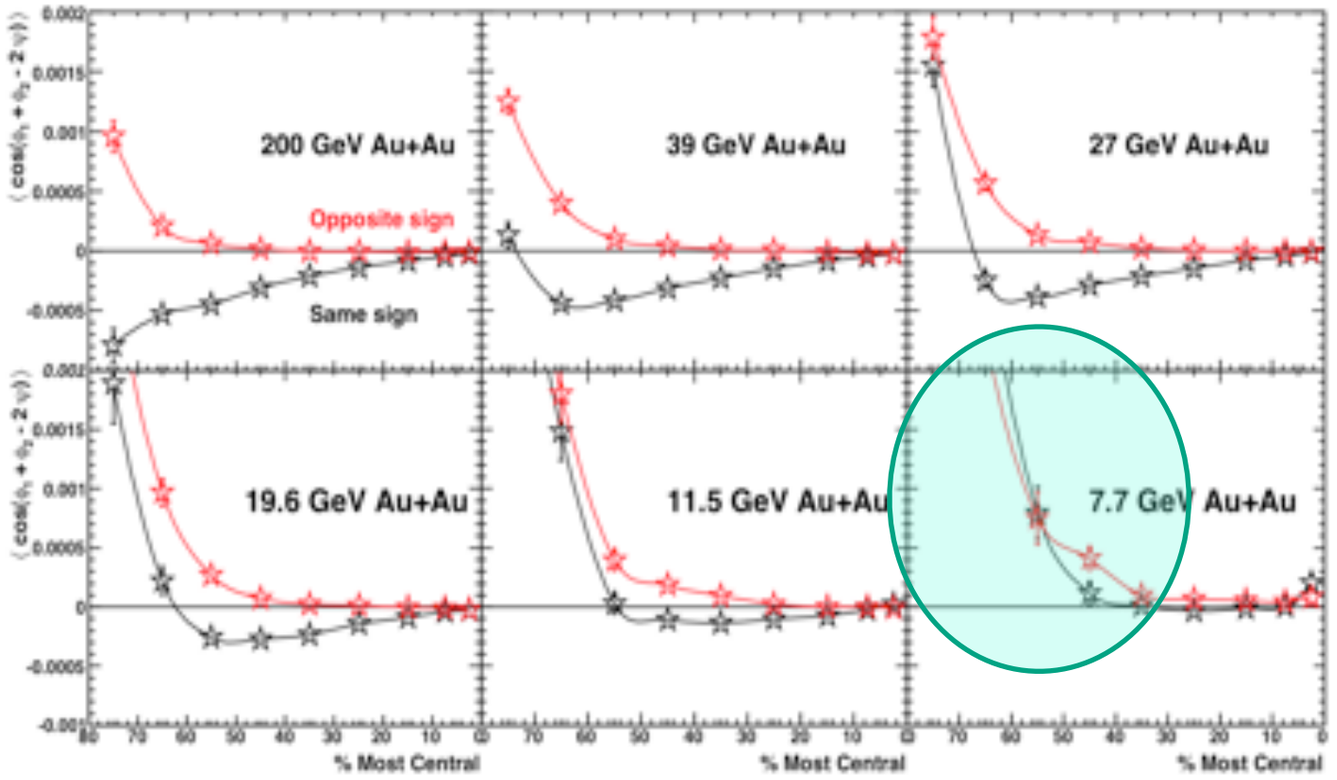


Where is the end of the sQGP?

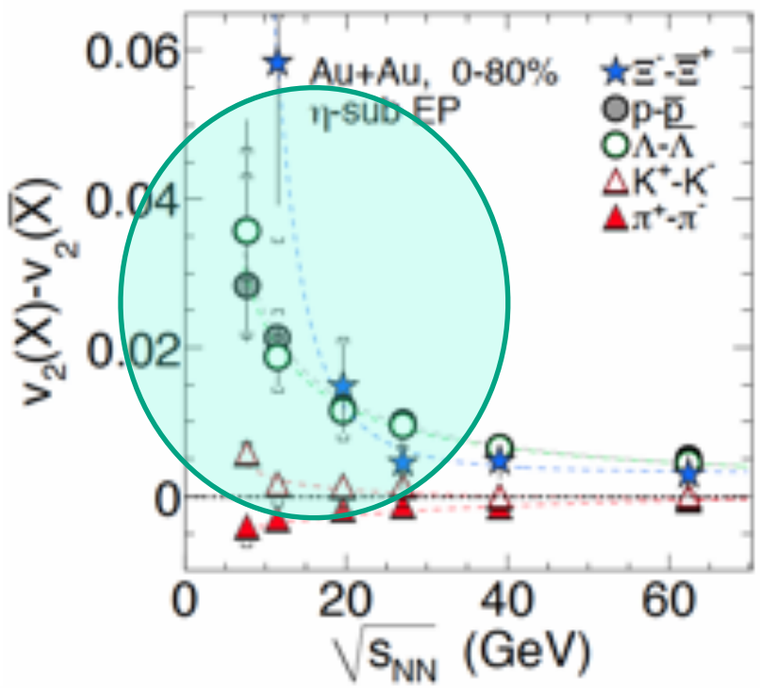
Jet-quenching



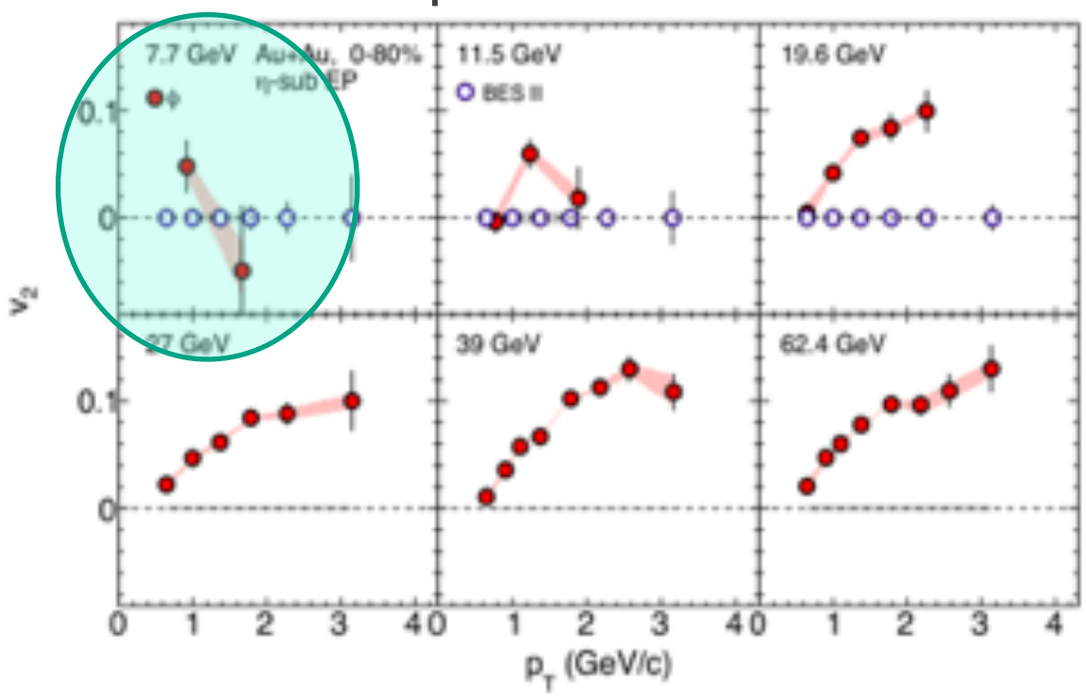
"Local Parity Violation"



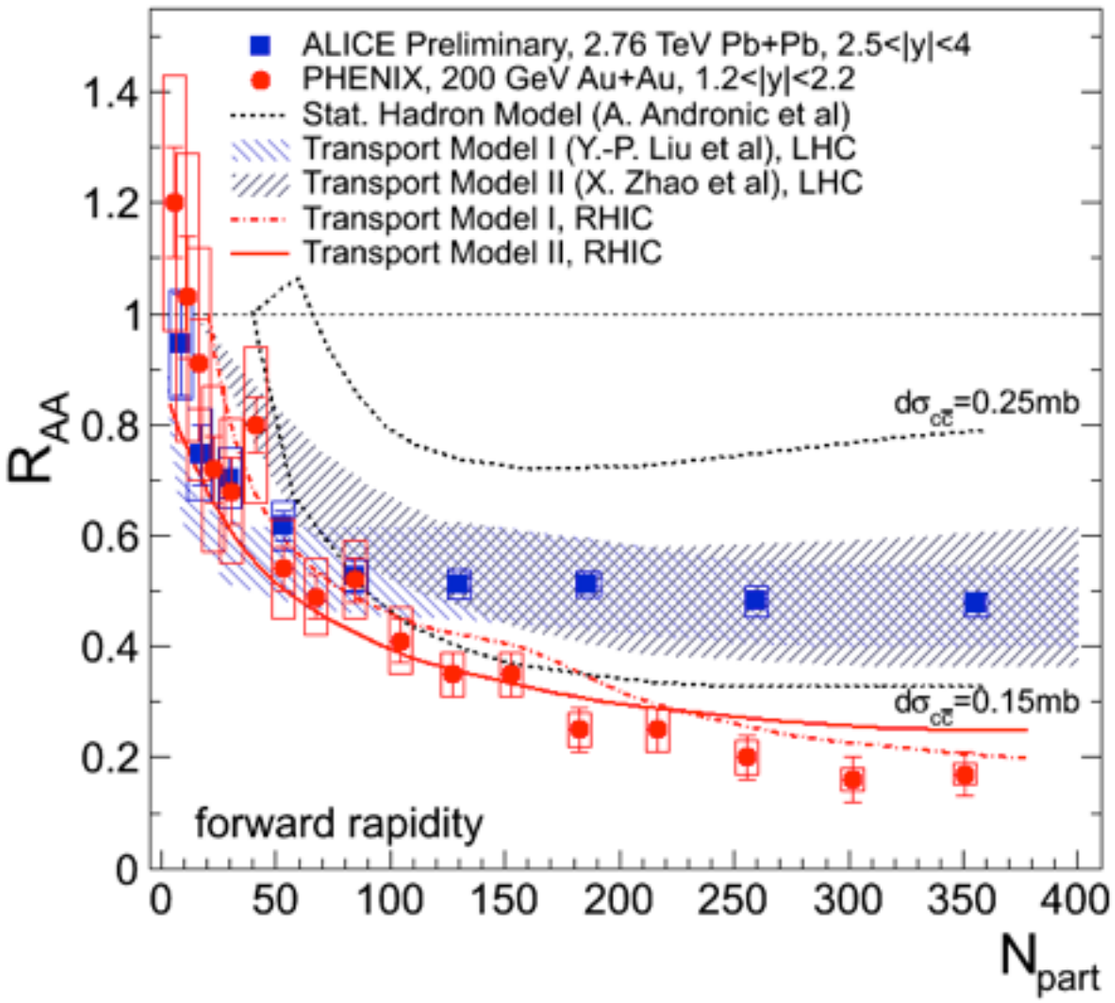
NQ Scaling in v_2



ϕ-meson flow

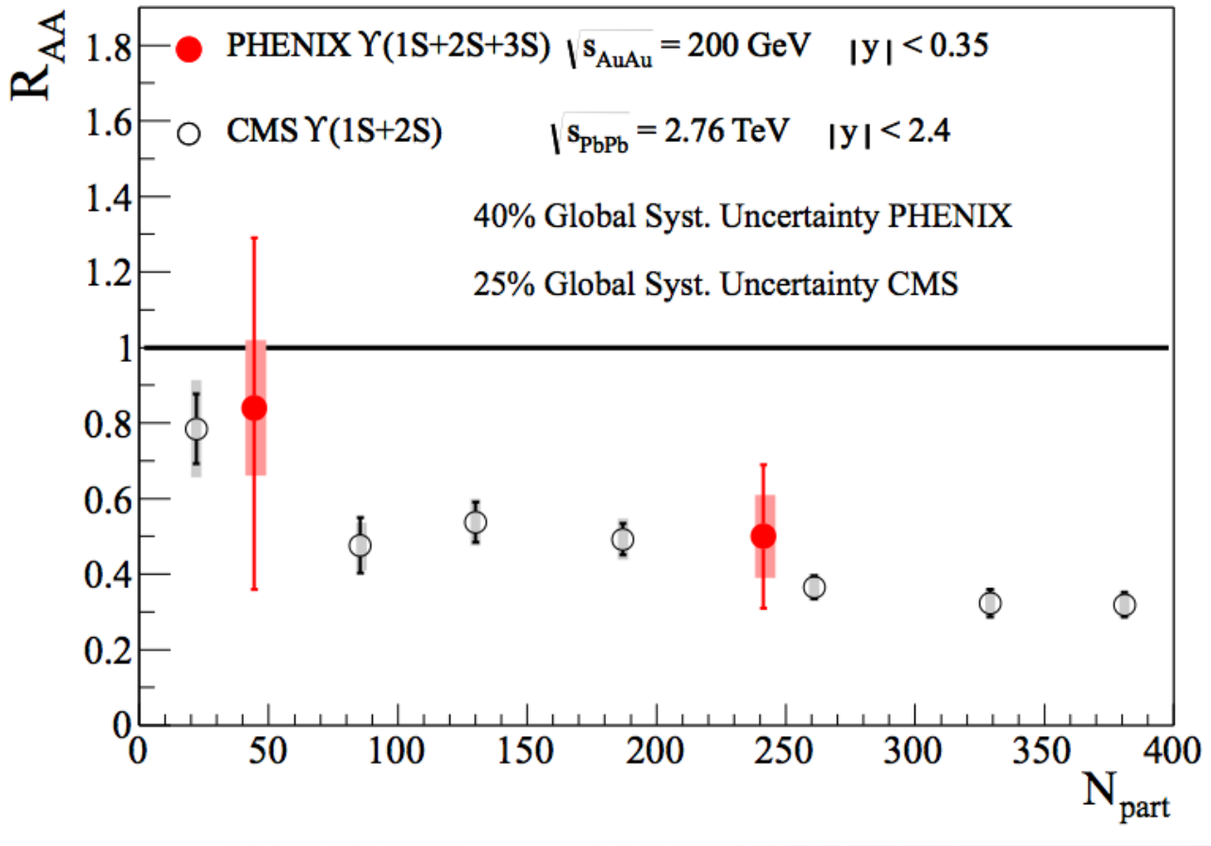


PHENIX: Quarkonium



Less J/ψ suppression at LHC than at RHIC, at mid-rapidity and mid-forward rapidities.

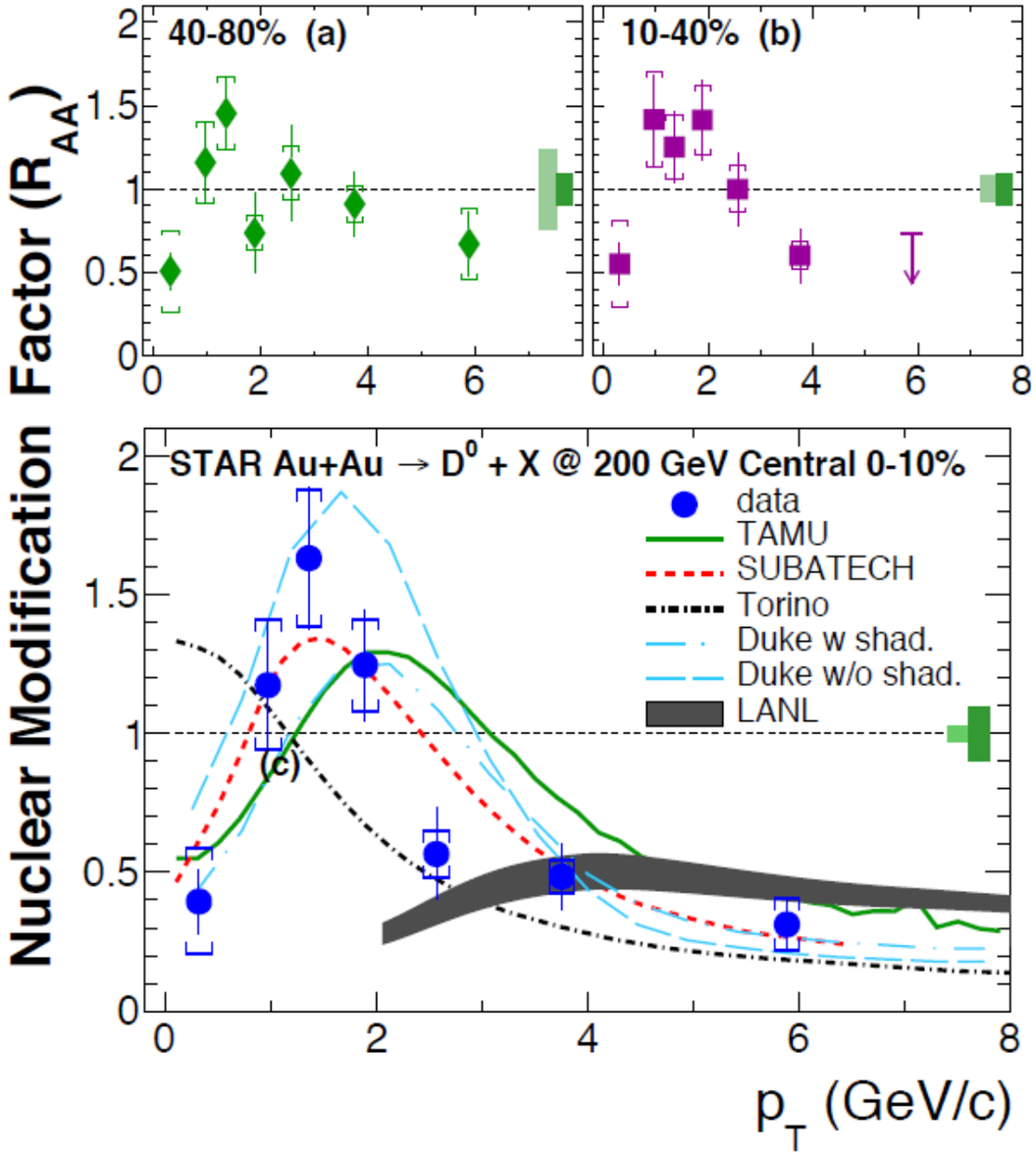
c-cbar recombination required to explain measurements.

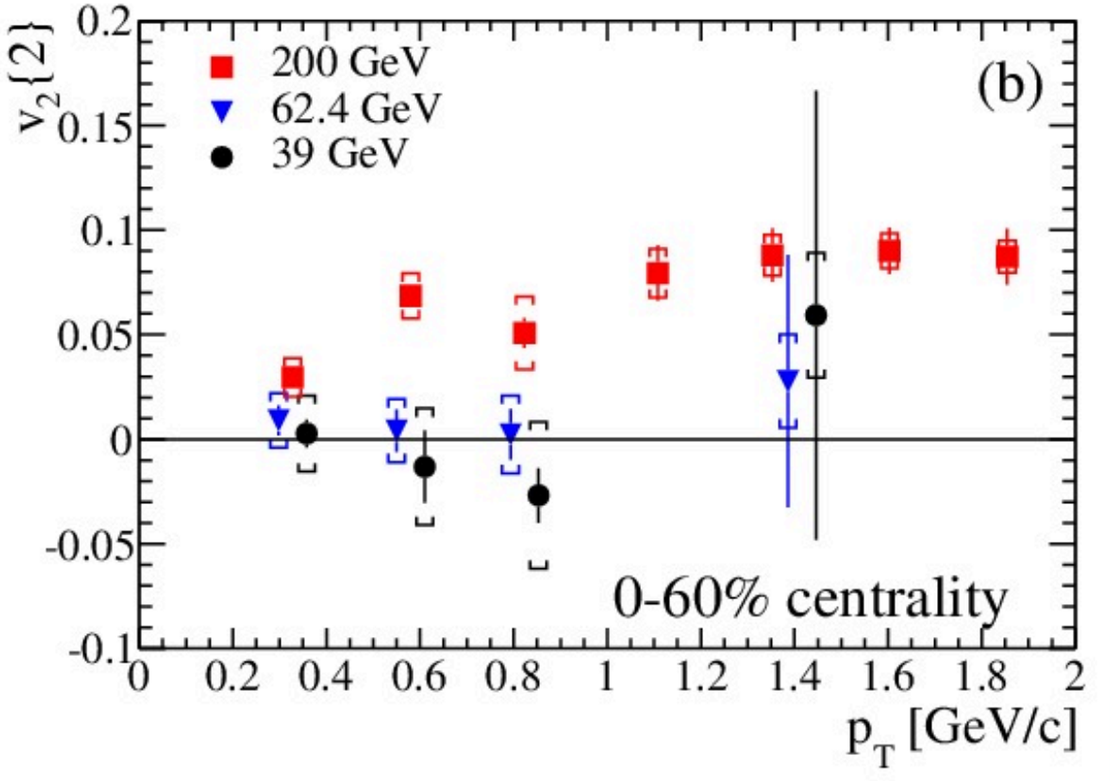


First measurement of unresolved Υ states.

PHENIX result is consistent with CMS result.
Consistent with disappearance of Υ(3S).

STAR: D^0 meson

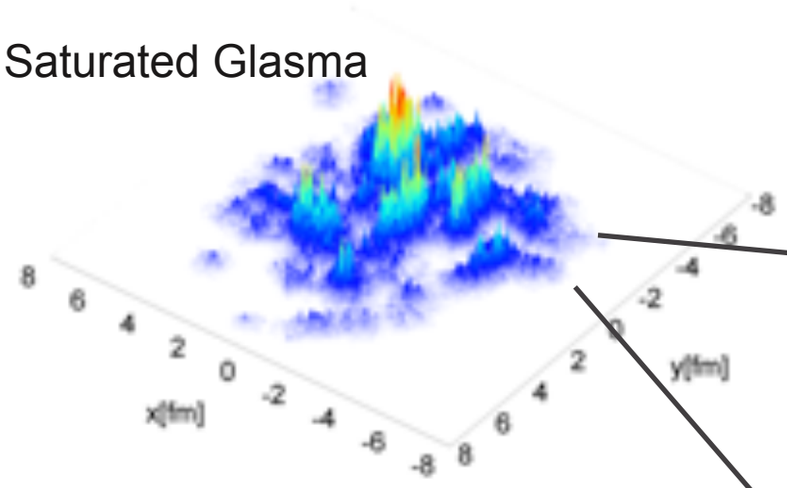




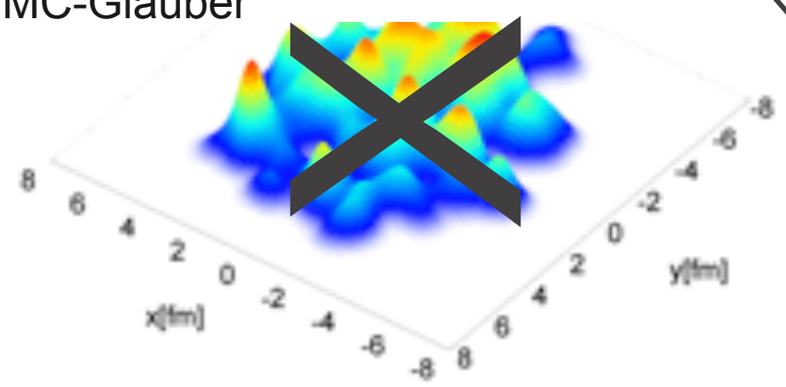
Identified D^0 meson spectrum confirms strong suppression of fast c quarks and collective flow.

sQGP: RHIC vs. LHC

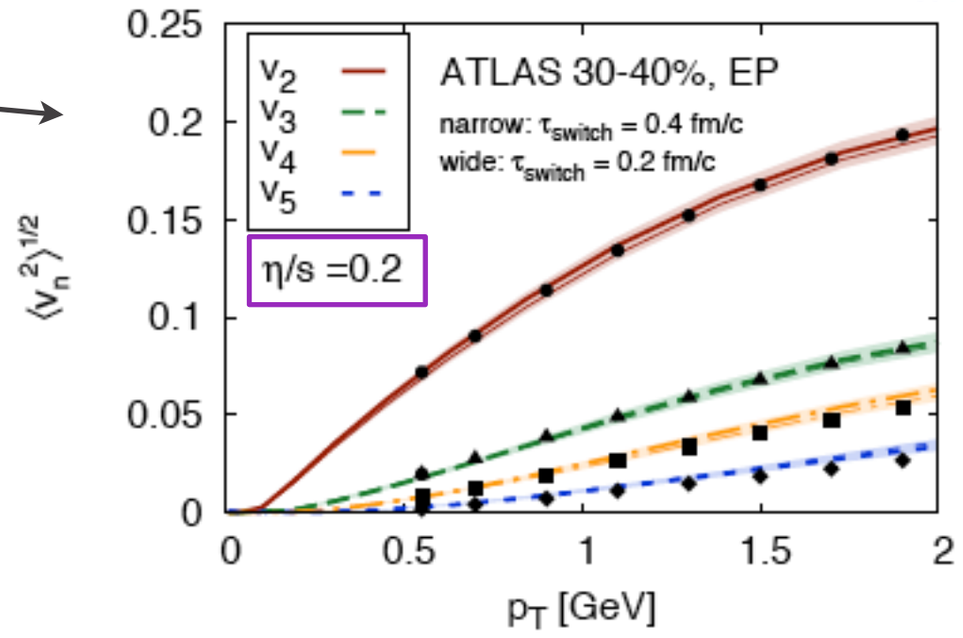
Saturated Glasma



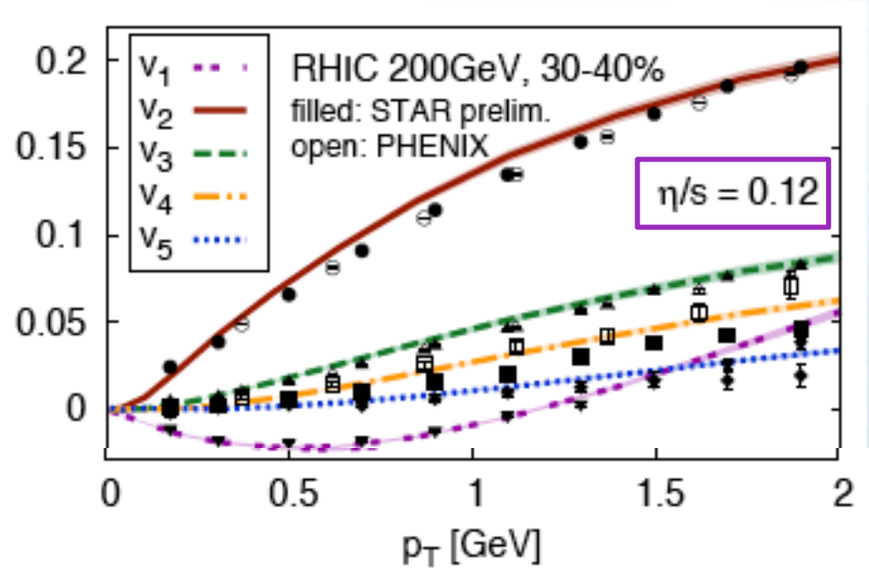
MC-Glauber



Gale, Jeon, Schenke, Tribedy, Venugopalan, arXiv:1209.6330



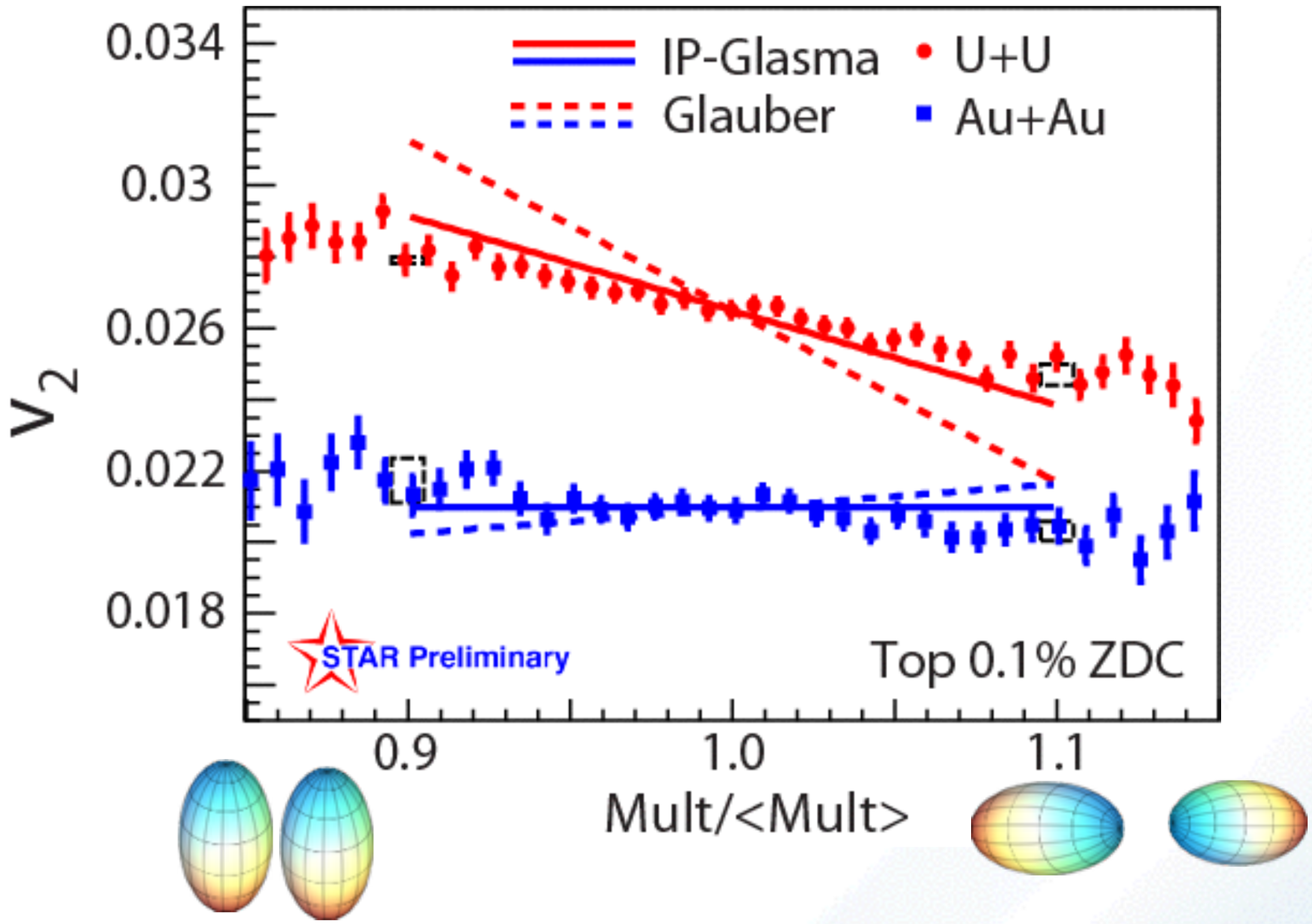
LHC



RHIC

B. Schenke
IUPAP Young Scientists Award 2013
DOE Early Career Award 2014

Versatility: U+U

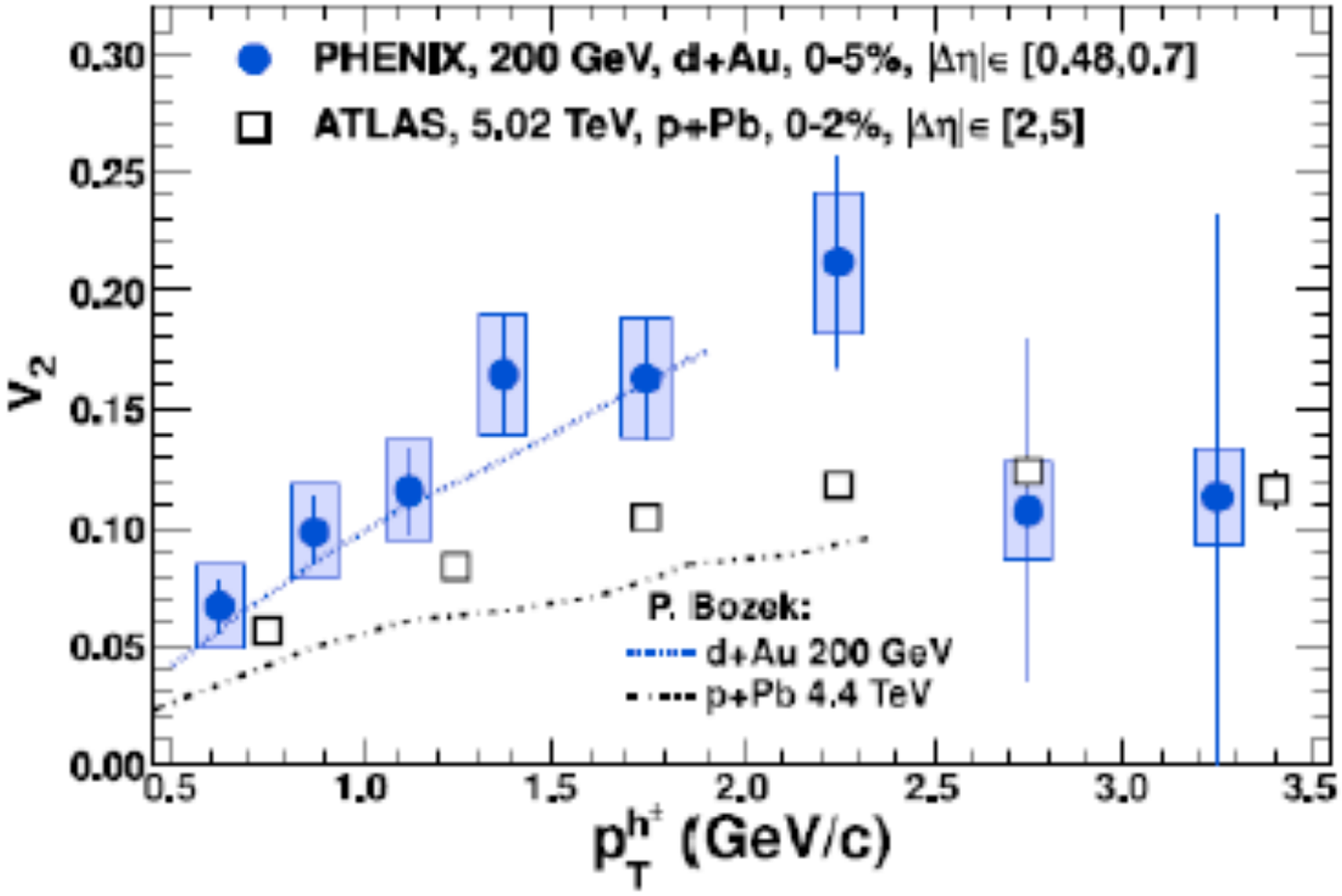


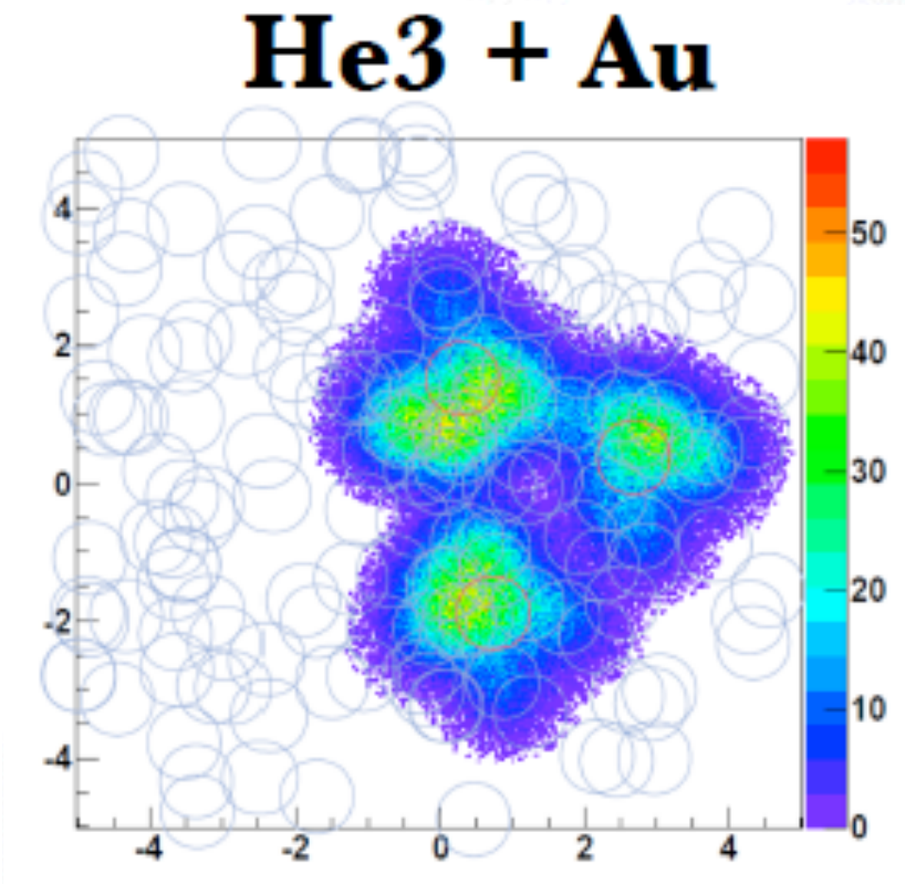
Deformed geometry of U+U allows discrimination between models of initial state fluctuations.

QGP in p+Pb and d+Au ?

Deuteron has a much larger average ε_2
RHIC has done it!

^{3}He generates a larger ε_3
RHIC is ran ^{3}He+Au in Run-14!

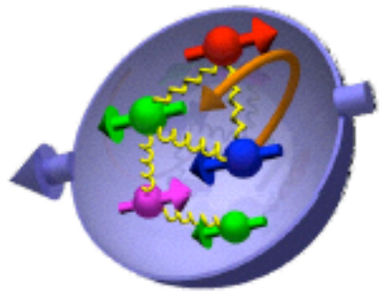


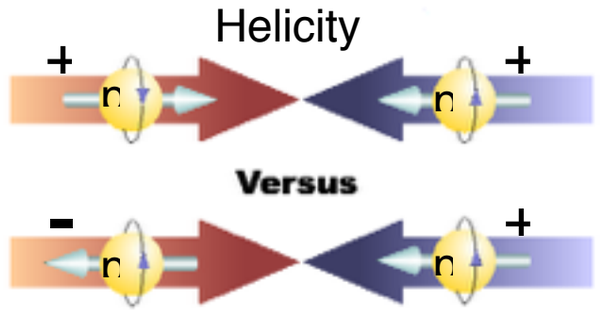


PHENIX: nucl-ex/1303.1794 [PRL 111 (2013) Highlight]

Where is the proton spin?

$$S = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$





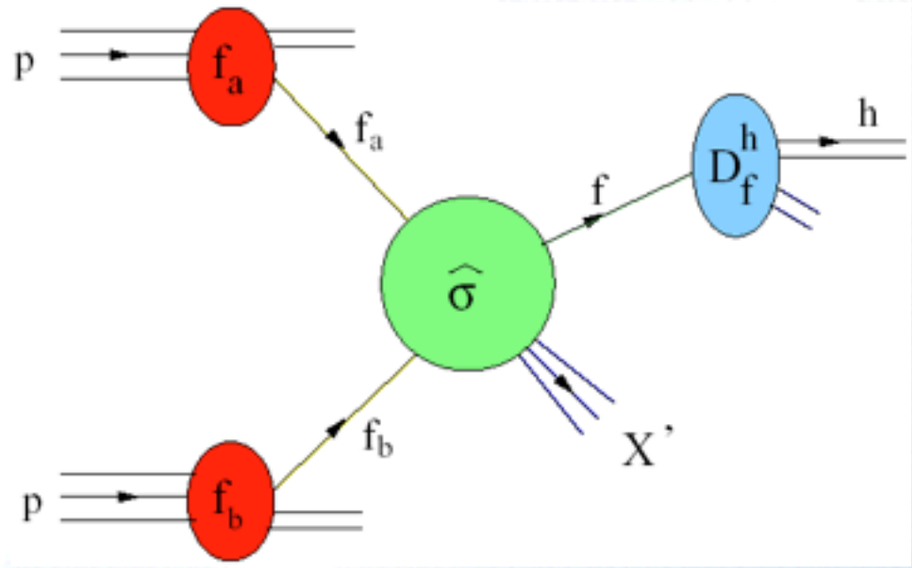
- **Polarized DIS tells us that ΔΣ ≈ 0.3**

$$A_{LL} = \frac{d\sigma_{++} - d\sigma_{+-}}{d\sigma_{++} + d\sigma_{+-}}$$

- **Q^2 evolution in polarized DIS gives information on gluon polarization but limited kinematic coverage leaves ΔG poorly constrained**

- **A primary goal of RHIC Spin program is to map Δg(x)**

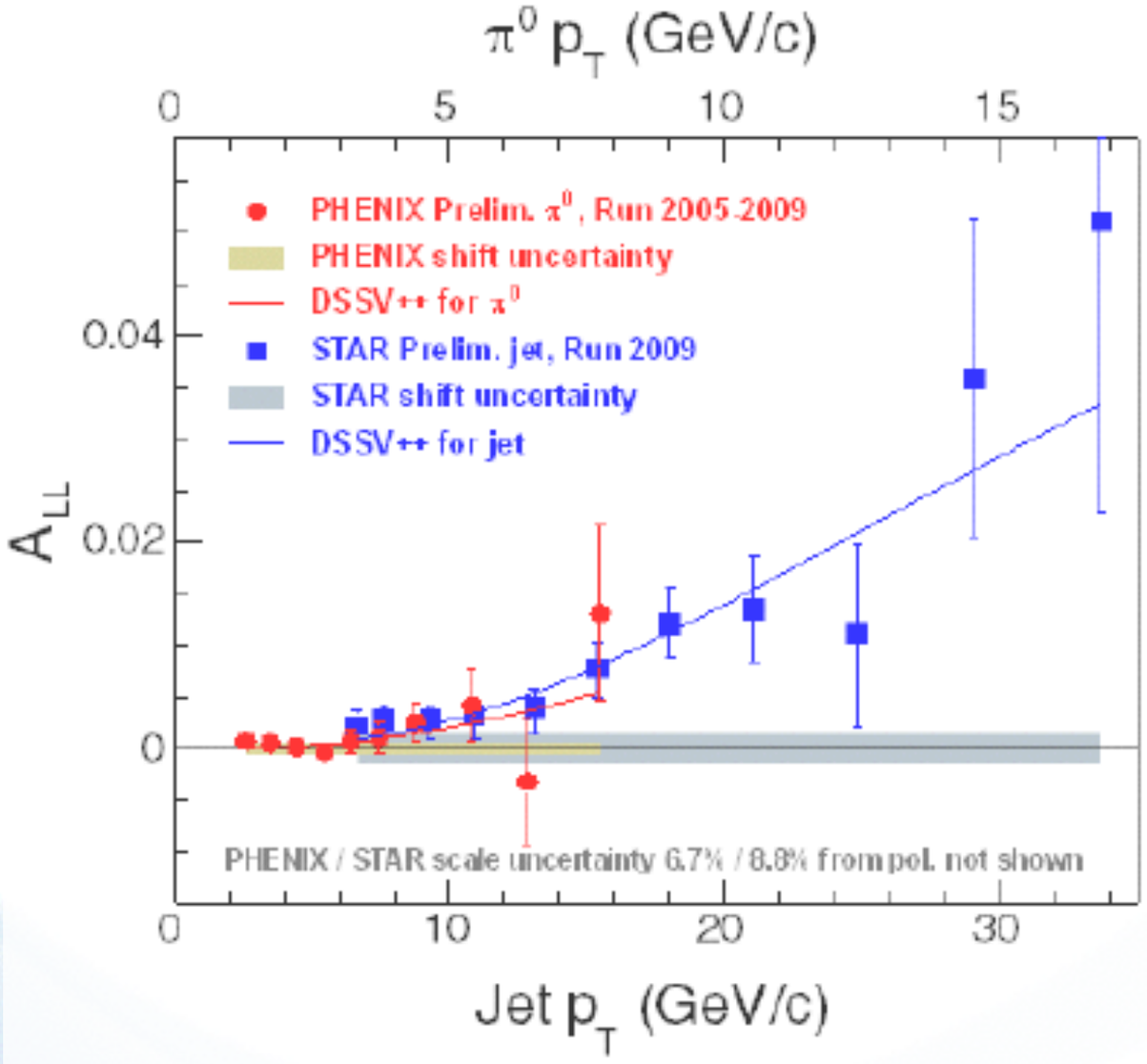
$$\Delta G = \int_0^1 \Delta g(x)\,dx$$



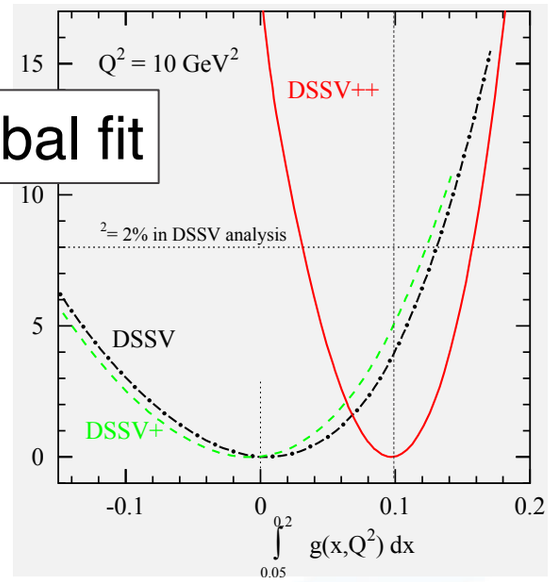
$$A_{LL} \propto [\omega_{gg}]\Delta g\Delta g + [\omega_{gq}\Delta q]\Delta g + [\omega_{qq}\Delta q\Delta q]$$

Δg from π^0 and jets

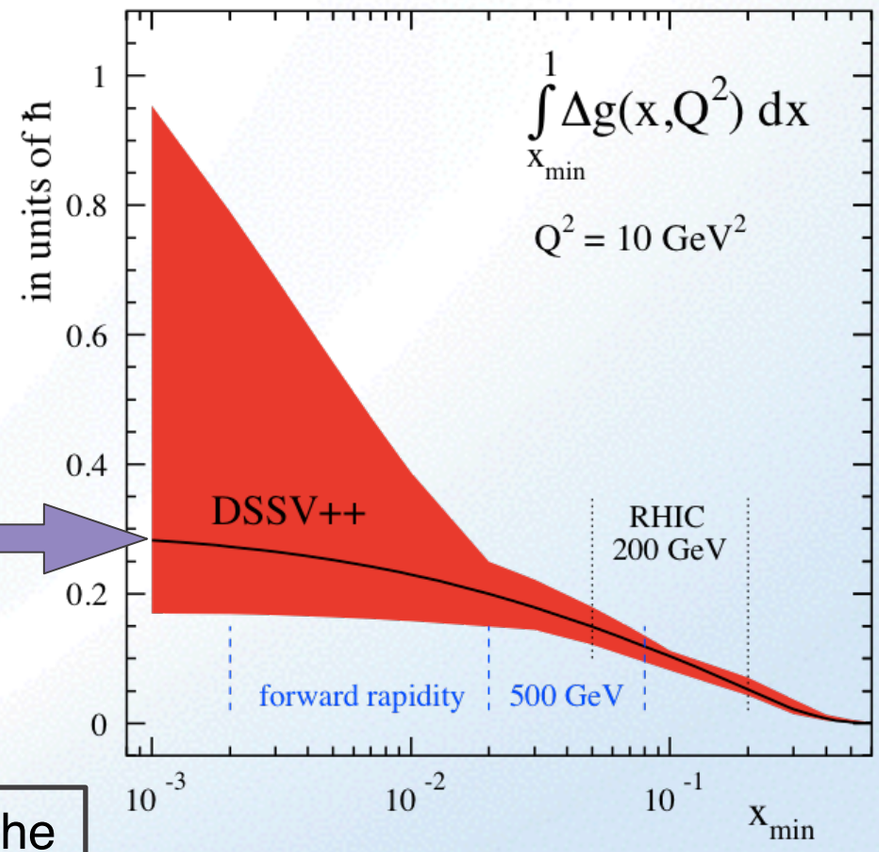
PHENIX: π^0 production
STAR: jet production



QCD global fit

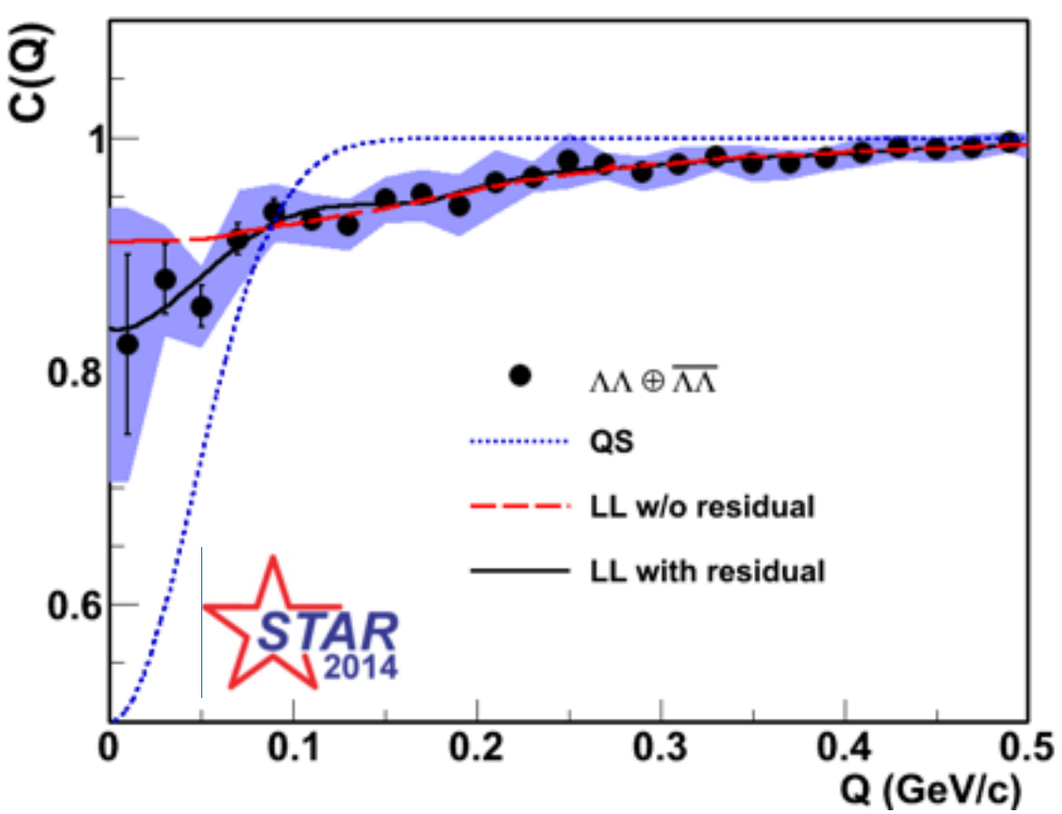


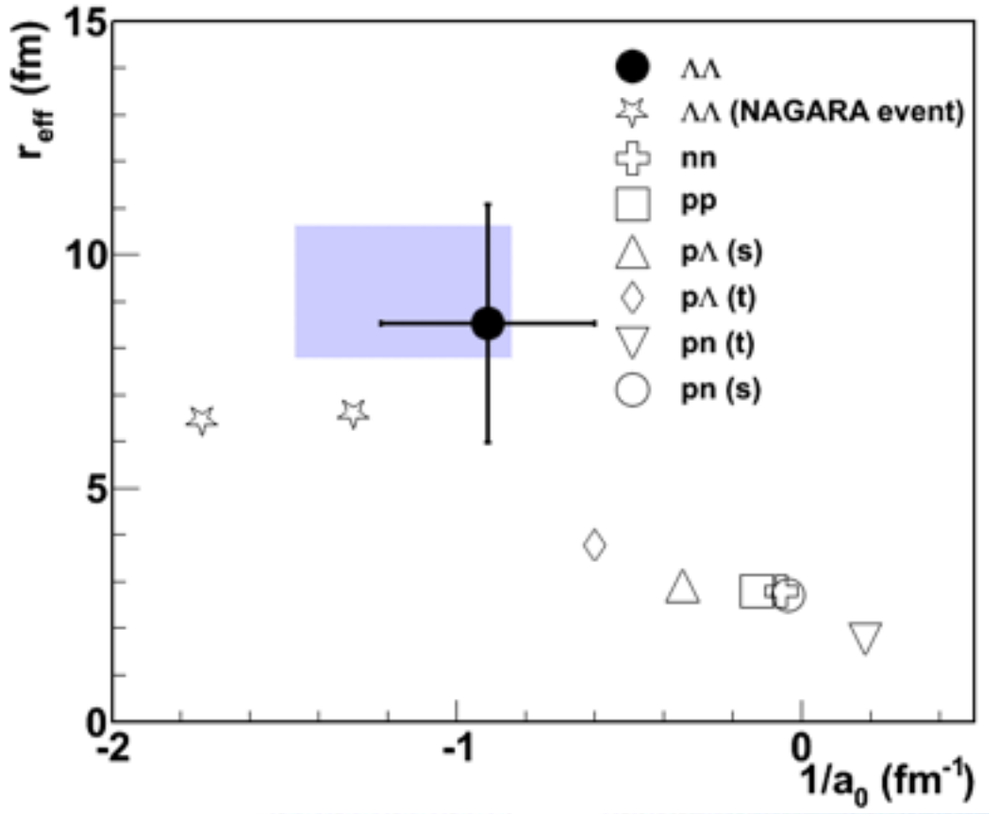
$$\int_{0.05}^{0.2} \Delta g(x)\,dx = 0.1 \pm^{0.06}_{0.07}$$



~60% of the proton spin?

ΛΛ Interaction

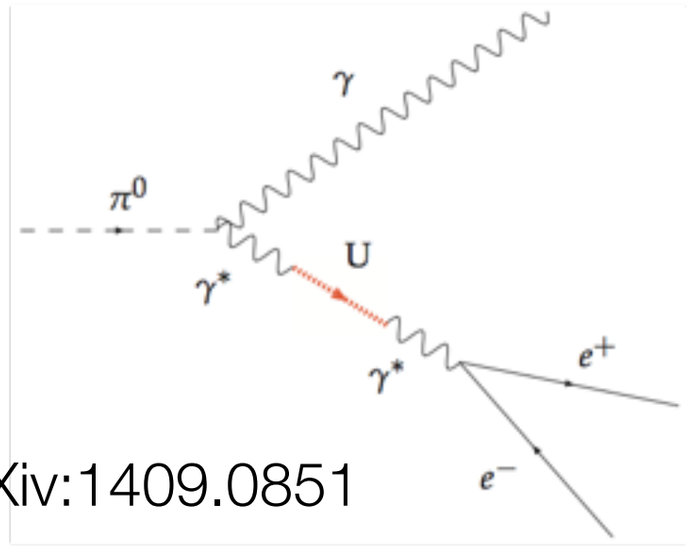




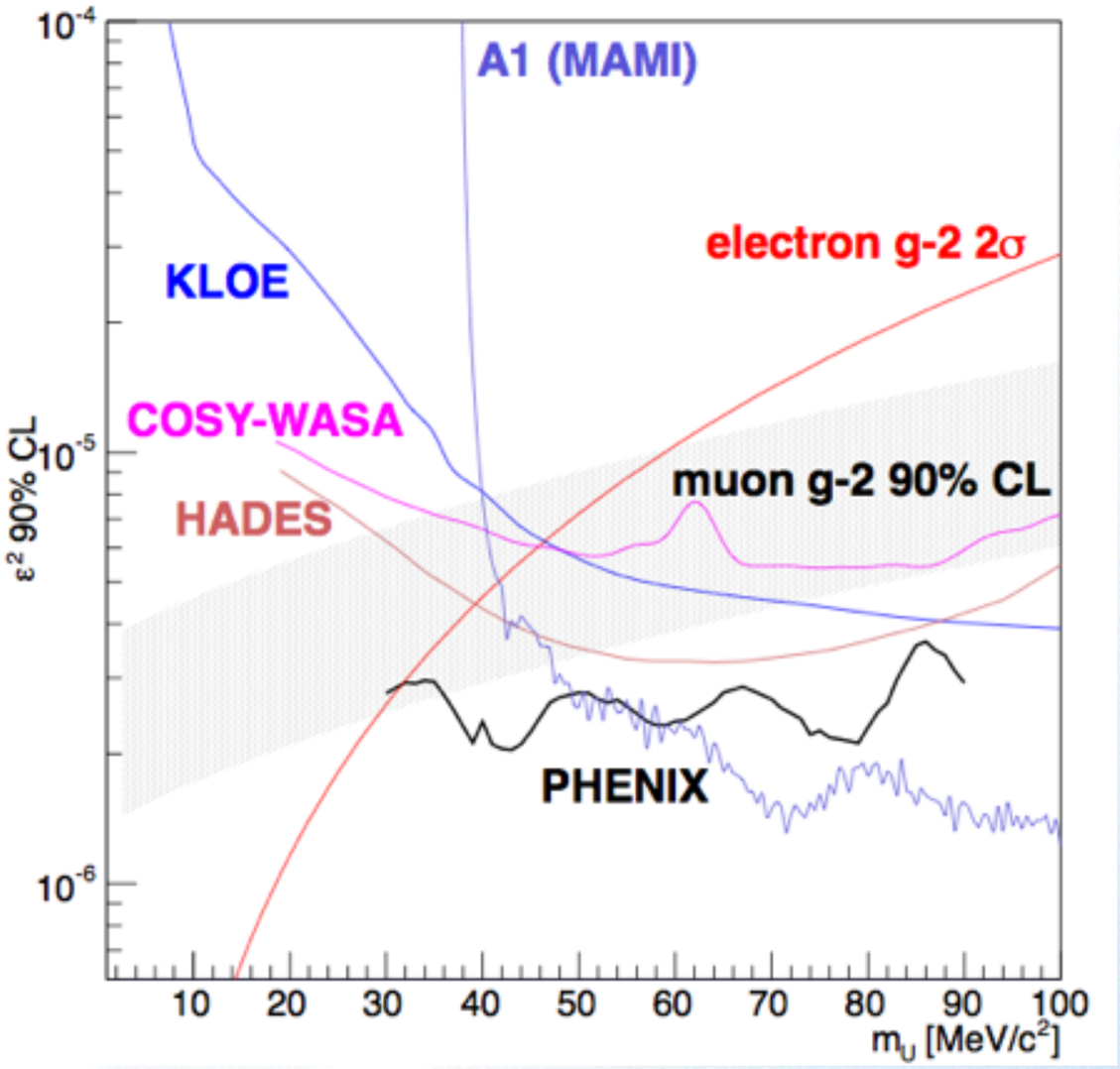
- Likely (weak) ΛΛ attractive interaction
- Scattering length consistent with NAGARA event
- No ΛΛ resonance
- Probably no H di-baryon bound state
- Paper submitted to Phys.Rev.Lett. (arxiv:1408.4360)

Dark photons?

PHENIX: Excellent electron ID and e^+e^- mass resolution – huge sample of π^0 Dalitz decays



arXiv:1409.0851



With recent combined limits, essentially all phase space for the dark photon as an explanation of the $(g\text{-}2)_\mu$ anomaly has been ruled out.

Completing RHIC's scientific mission

Main Questions

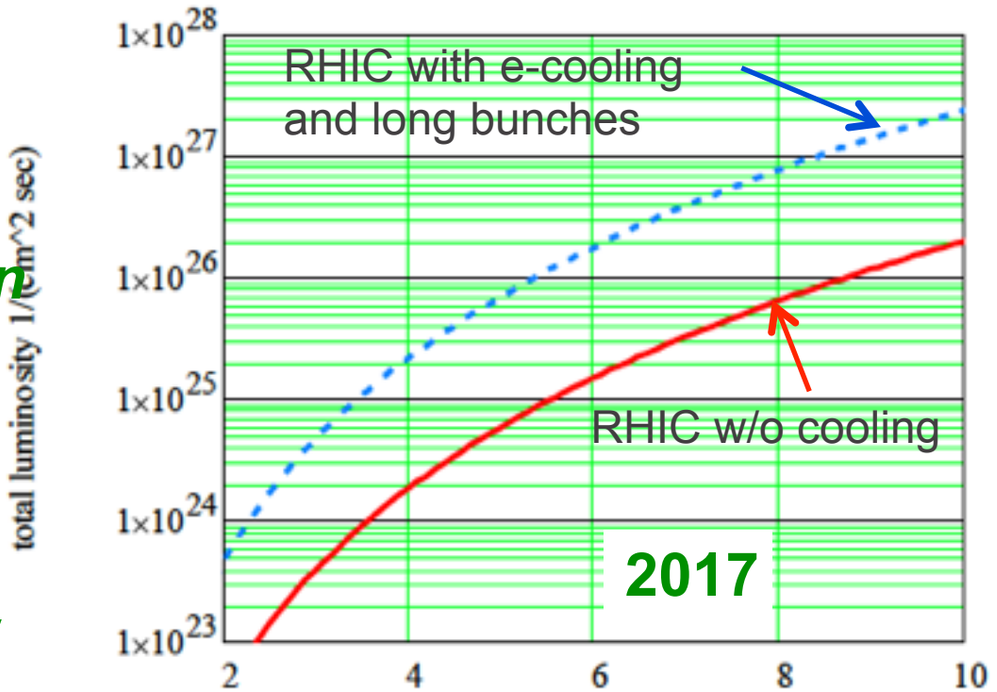
- What do we need to know about the initial state? Is it a weakly coupled color glass condensate? How does it thermalize?
- What do the data tell us about the initial conditions for the hydro-dynamic expansion? Can we determine them unambiguously?
- What is the smallest collision system that behaves collectively?
- What does the QCD phase diagram look like? Does it contain a critical point in the HG-QGP transition region? Does the HG-QGP transition become a first-order phase transition for large μ_B?
- What can jets and heavy flavors tell us about the structure of the strongly coupled QGP?
- What do quarkonia (and and heavy quarks) data tell us about quark deconfinement and hadronization?
- Can we find unambiguous proof for chiral symmetry restoration?
- What is the mechanism of transverse spin dynamics in QCD?
- How large is the contribution of gluons to the proton spin?

Planned RHIC Upgrades

Machine upgrades:

E-lenses
Vertex compression

Bunched beam electron cooling for low-E beams for ~10x luminosity

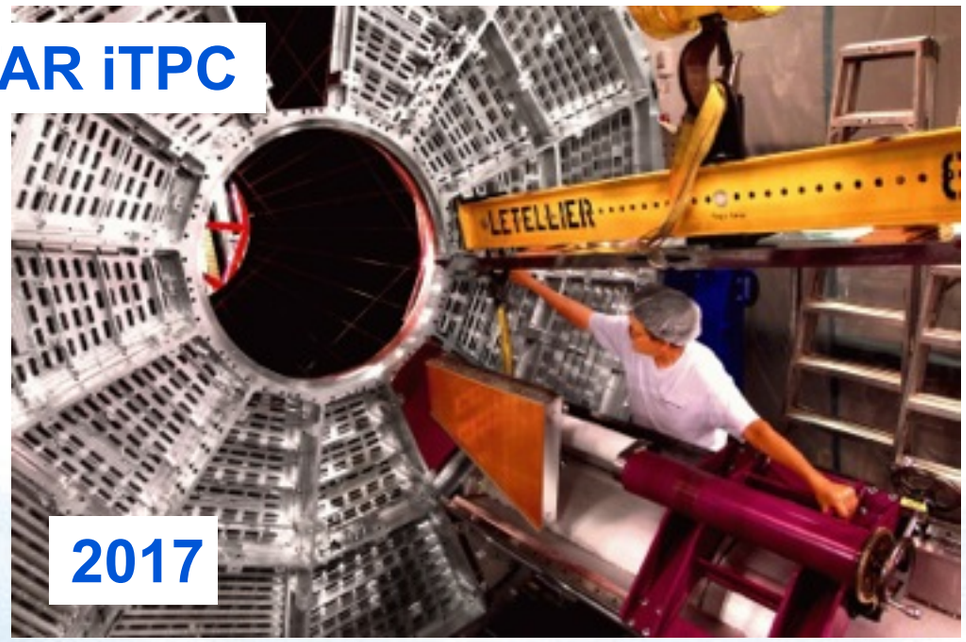


Detector upgrades:

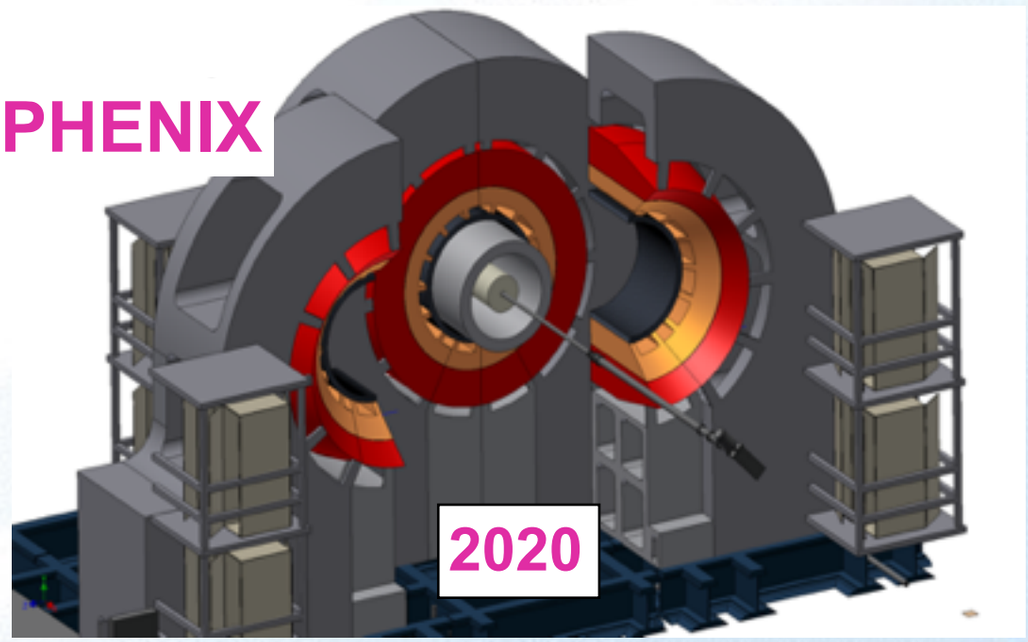
- **PHENIX MPC-EX**
- **STAR iTPC**
- **STAR Roman Pots**
- **STAR FMS Preshower**

- **sPHENIX solenoid, EMCAL + HCAL for jet physics @ RHIC**

STAR iTPC



sPHENIX



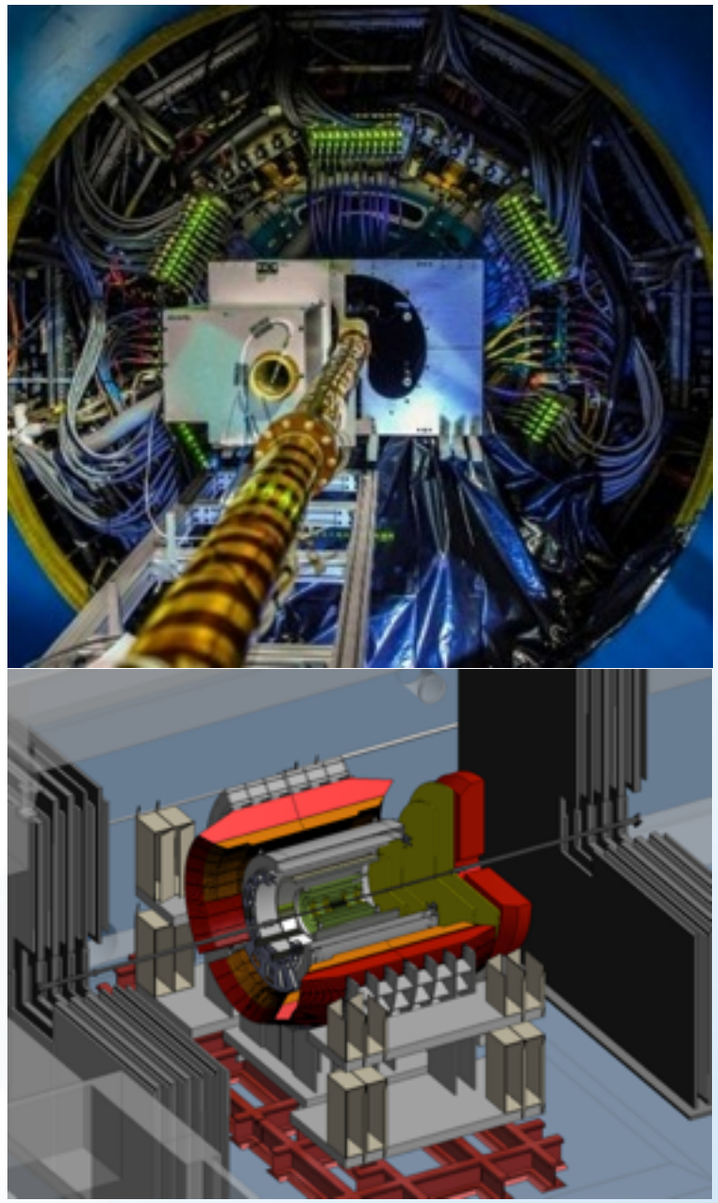
Completing the RHIC Mission

Status:

- RHIC-II configuration is now complete
  - Vertex detectors in STAR (HFT) and PHENIX
- RHIC Run 14 – Integrated Au+Au luminosity exceeds all previous Au+Au runs combined

Plan: Complete the RHIC Mission in 3 campaigns:

- **2014–16:** Heavy flavor probes of the QGP
- 2017: Install low energy e-cooling
- **2018/19:** High precision scan of the QCD phase diagram
- 2020: Complete sPHENIX upgrade, install STAR forward upgrades
- **2021/22:** Precision measurements of jet quenching and quarkonium suppression
- 2023-25: RHIC shutdown and transition to eRHIC



RHIC remains a unique discovery facility:
~3,000 citations/year, ~30 PhD's per year

Proposed run schedule for RHIC

Years	Beam Species and Energies	Science Goals	New Systems Commissioned
2014	15 GeV Au+Au 200 GeV Au+Au ^{3}He+Au at 200 GeV	Heavy flavor flow, energy loss, thermalization, etc. Quarkonium studies QCD critical point search	Electron lenses 56 MHz SRF STAR HFT STAR MTD
2015-16	Pol. p+p at 200 GeV p+Au, p+Si at 200 GeV High statistics Au+Au Pol. p+p at 510 GeV? Au+Au at 62 GeV?	Extract η/s(T) + constrain initial quantum fluctuations More heavy flavor studies Sphaleron tests Transverse spin physics	PHENIX MPC-EX Coherent e-cooling test
2017	No Run		Low energy e-cooling upgrade
2018-19	5-20 GeV Au+Au (BES-2)	Search for QCD critical point and onset of deconfinement	STAR ITPC upgrade Partial commissioning of sPHENIX (in 2019)
2020	No Run		Complete sPHENIX installation STAR forward upgrades
2021-22	200 GeV Au+Au with upgraded detectors Pol. p+p, p+Au at 200 GeV	Jet, di-jet, γ-jet probes of parton transport and energy loss mechanism Color screening for different quarkonia	sPHENIX
2023-24	No Runs		Transition to eRHIC

Goals for 2014-16 RHIC runs

- Precision determination of heavy quark interactions with the QGP; radiative vs. collisional energy loss.
- Heavy quark spectrum at hadronization to predict Q-Qbar recombination.
- Size dependence of collective effects for small systems.
- First study of polarized p+Au, p+Al interactions: A novel probe of parton saturation?
- Longitudinal and transverse spin effects in polarized p+p collisions (Sivers function, ΔG).
- Definitive measurement of gluon polarization over an extended x-range?
- Sign change of A_N between polarized e+p and p+p ?
- Beam energy dependence of heavy quark dynamics?

PAC recommendations

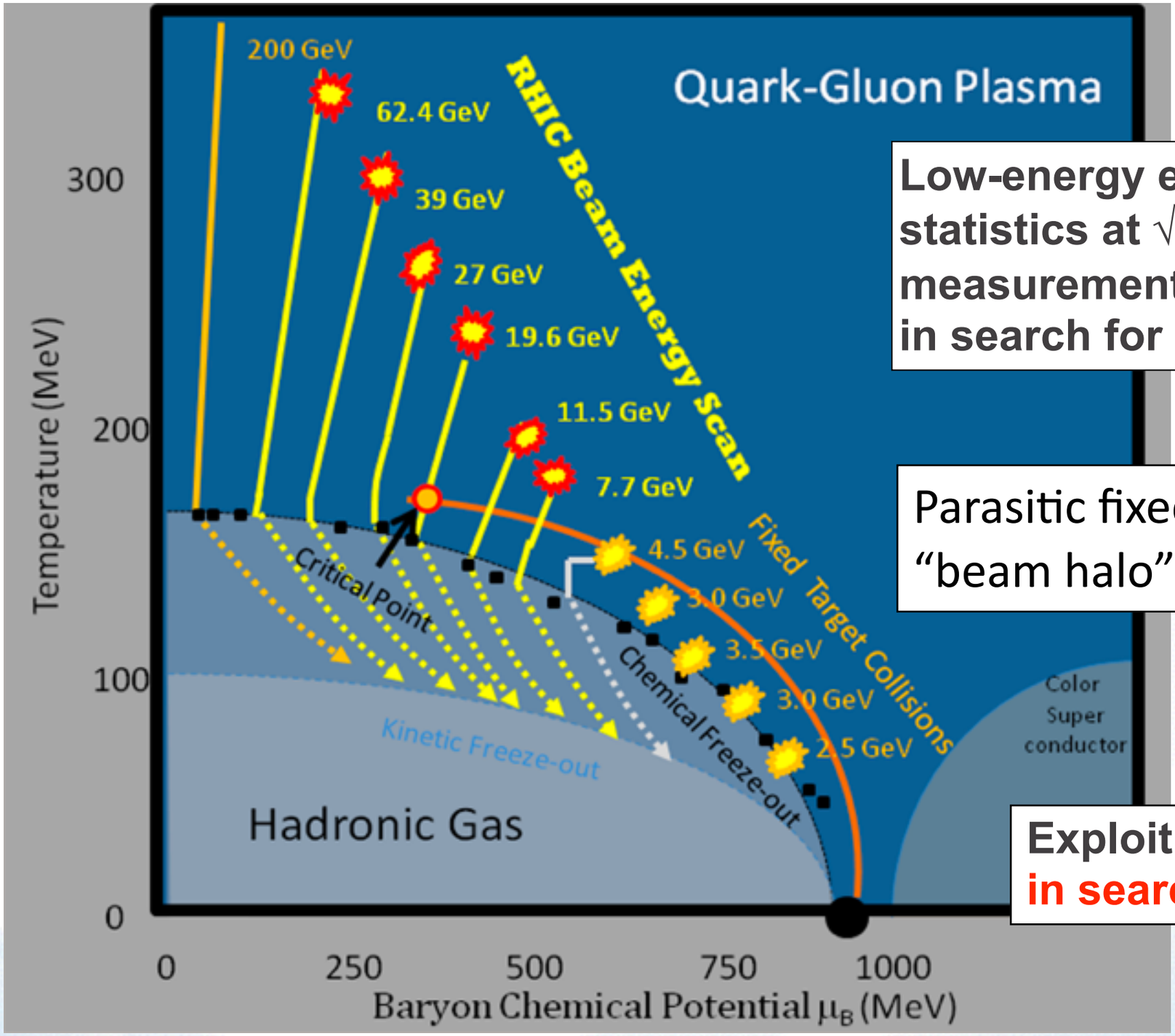
For Run 15 the PAC recommends the following (*in order of priority*):

- 9 weeks of polarized p+p collisions at $\sqrt{s_{NN}} = 200$ GeV, *and*
- 5 weeks of p+Au collisions at $\sqrt{s_{NN}} = 200$ GeV with transverse polarization of the proton
- 2 weeks of p+Al collisions at $\sqrt{s_{NN}} = 200$ GeV with transverse polarization of the proton

For Run 16 the PAC recommends the following

- 10 weeks of Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV
- 7 weeks of Au+Au and p+p collisions at $\sqrt{s_{NN}} = 62$ GeV, *or*
- 7 weeks of polarized p+p collisions at $\sqrt{s_{NN}} = 510$ GeV

Beam energy scan II



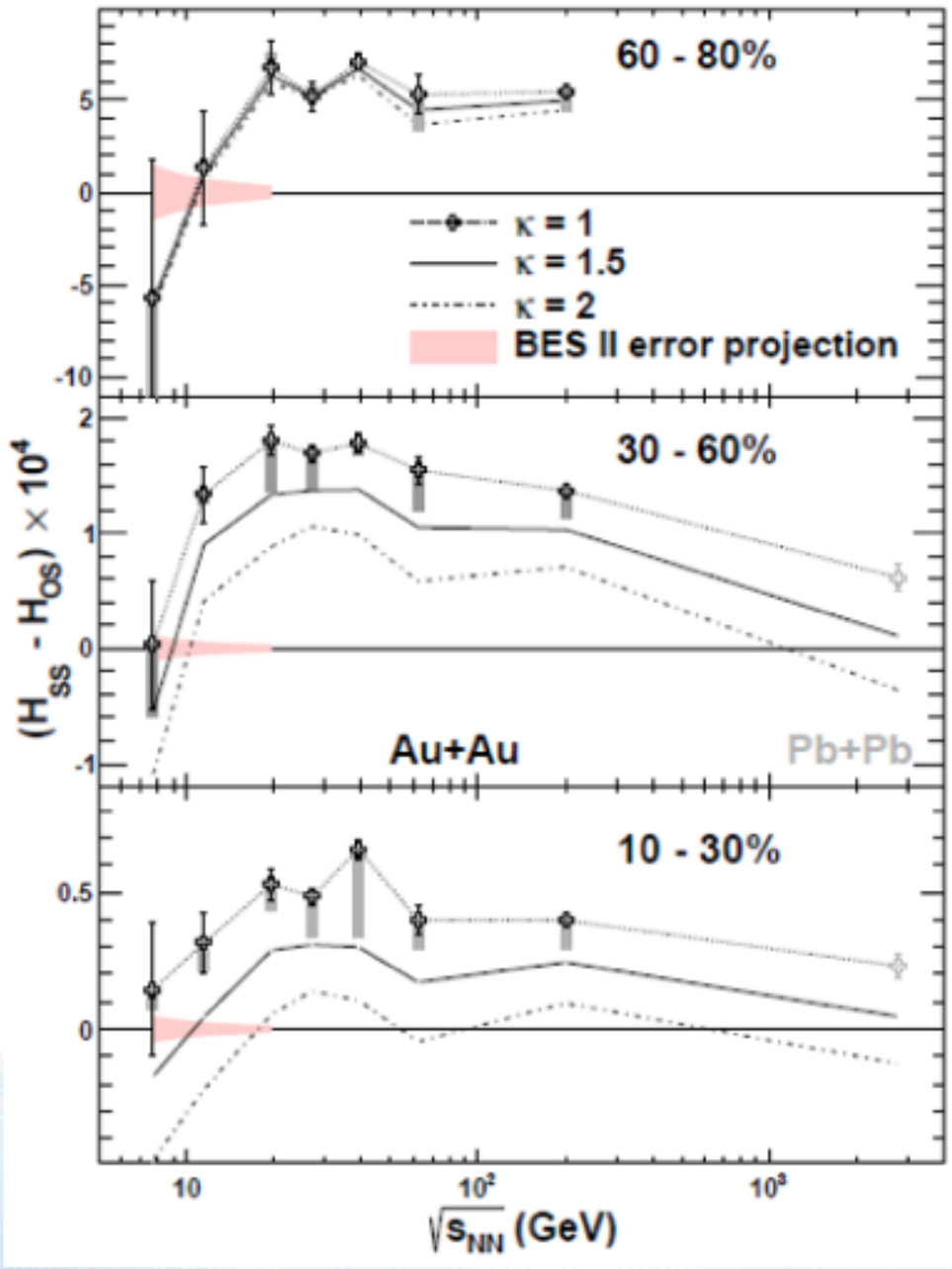
Low-energy e-cooling will improve statistics at $\sqrt{s}$ < 20 GeV for detailed measurements of sensitive quantities in search for critical point

Parasitic fixed target mode by utilizing "beam halo" inside STAR detector ?

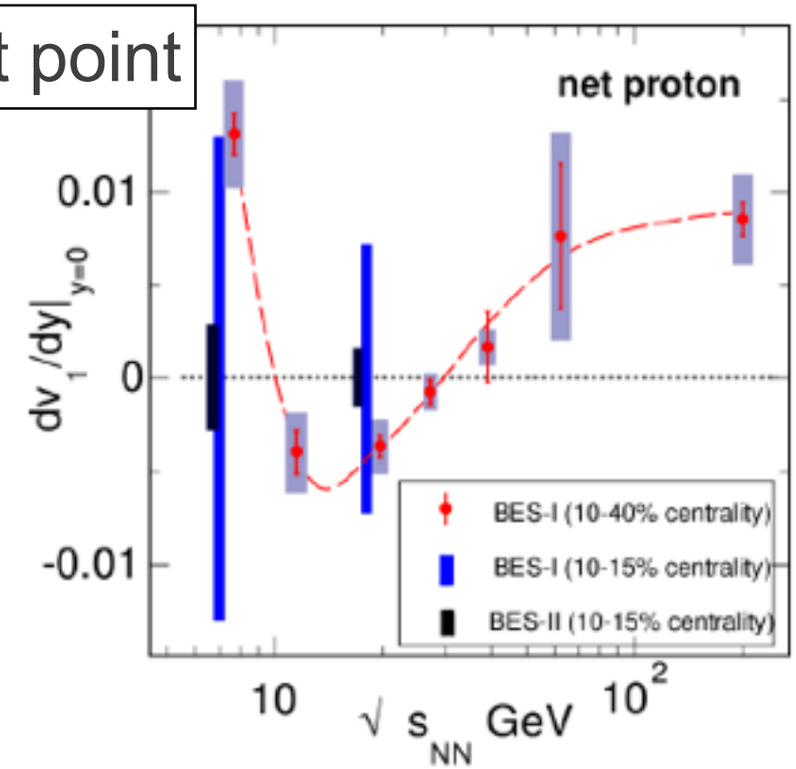
Exploit new discovery potential in search for a QCD critical point

BES-II highlights

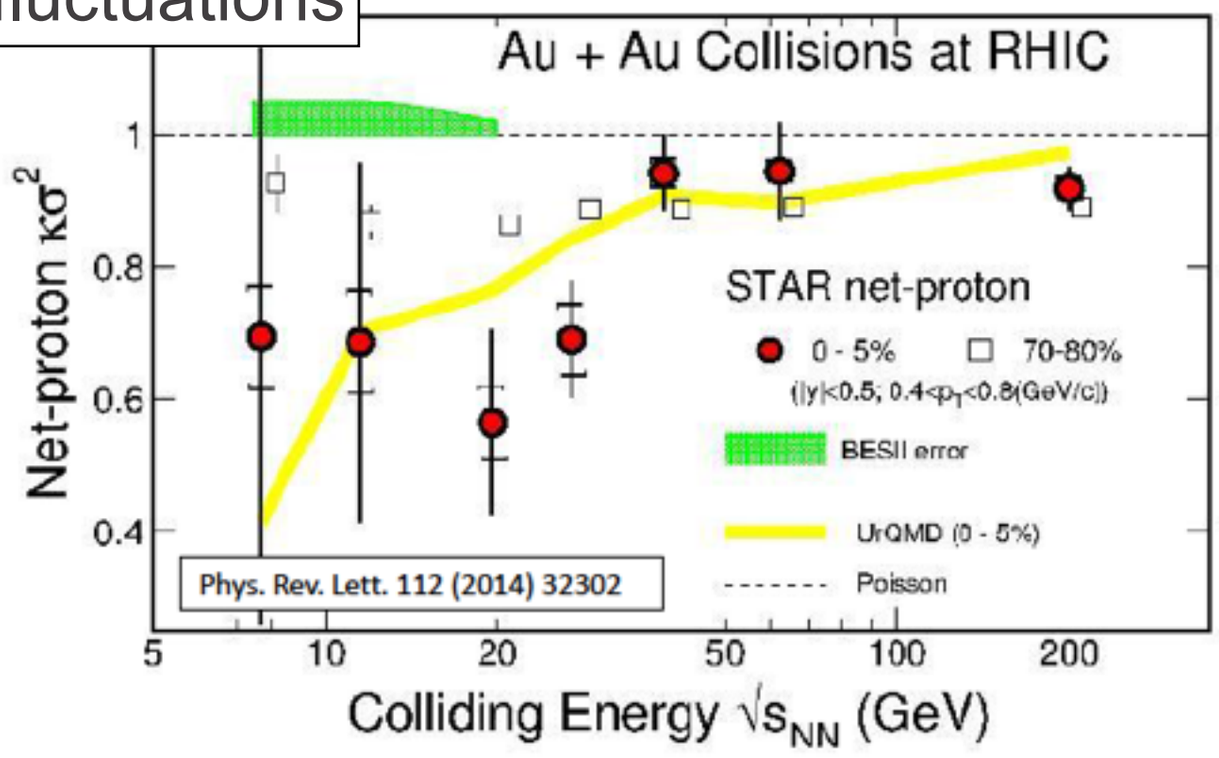
Chiral magnetic phenomena



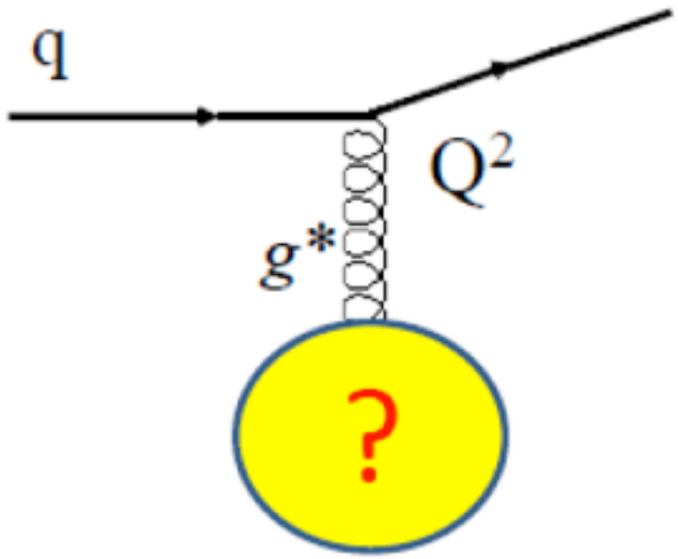
Softest point



Critical fluctuations



Probing the structure of the sQGP



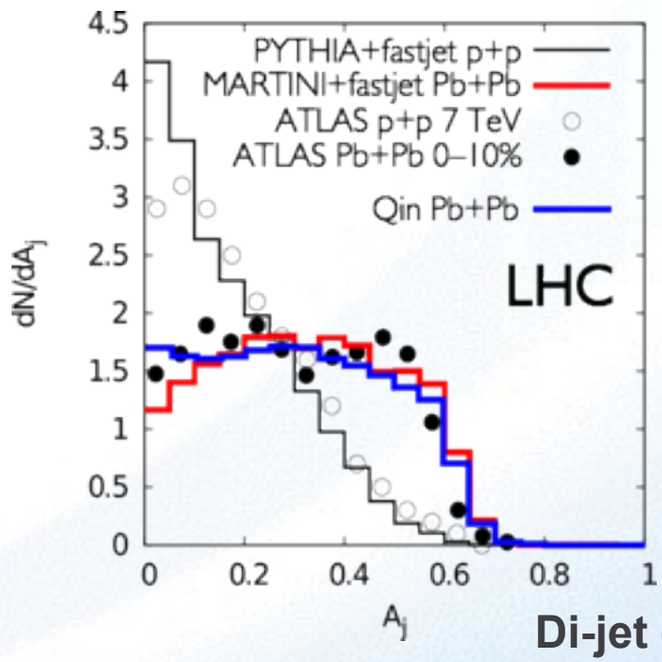
Low viscosity, rapid thermalization, and strong jet quenching are consequences of strong coupling

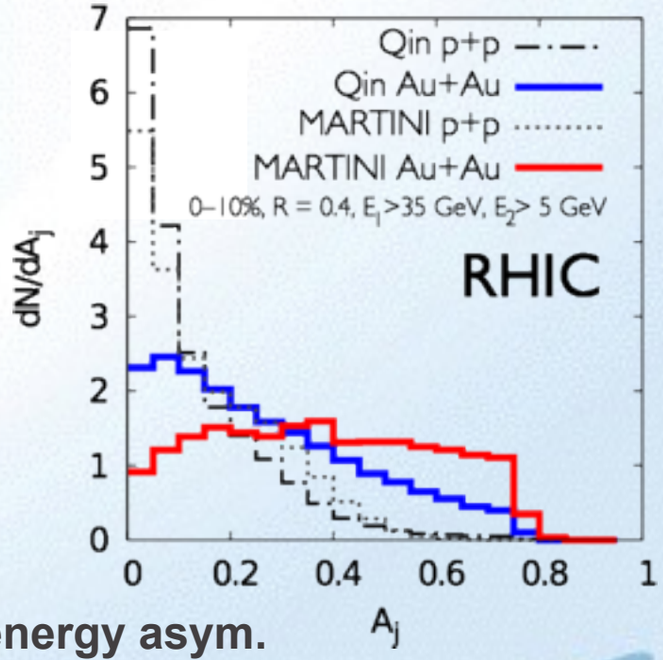
Determination of qhat(T), η/s(T) permits analysis of coupling strength

Requires measurements of jet, di-jet, γ-jet quenching, jet structure at multiple $\sqrt{s}$

sPHENIX upgrade will enable full jet reconstruction at RHIC

BaBar solenoid in its transfer frame

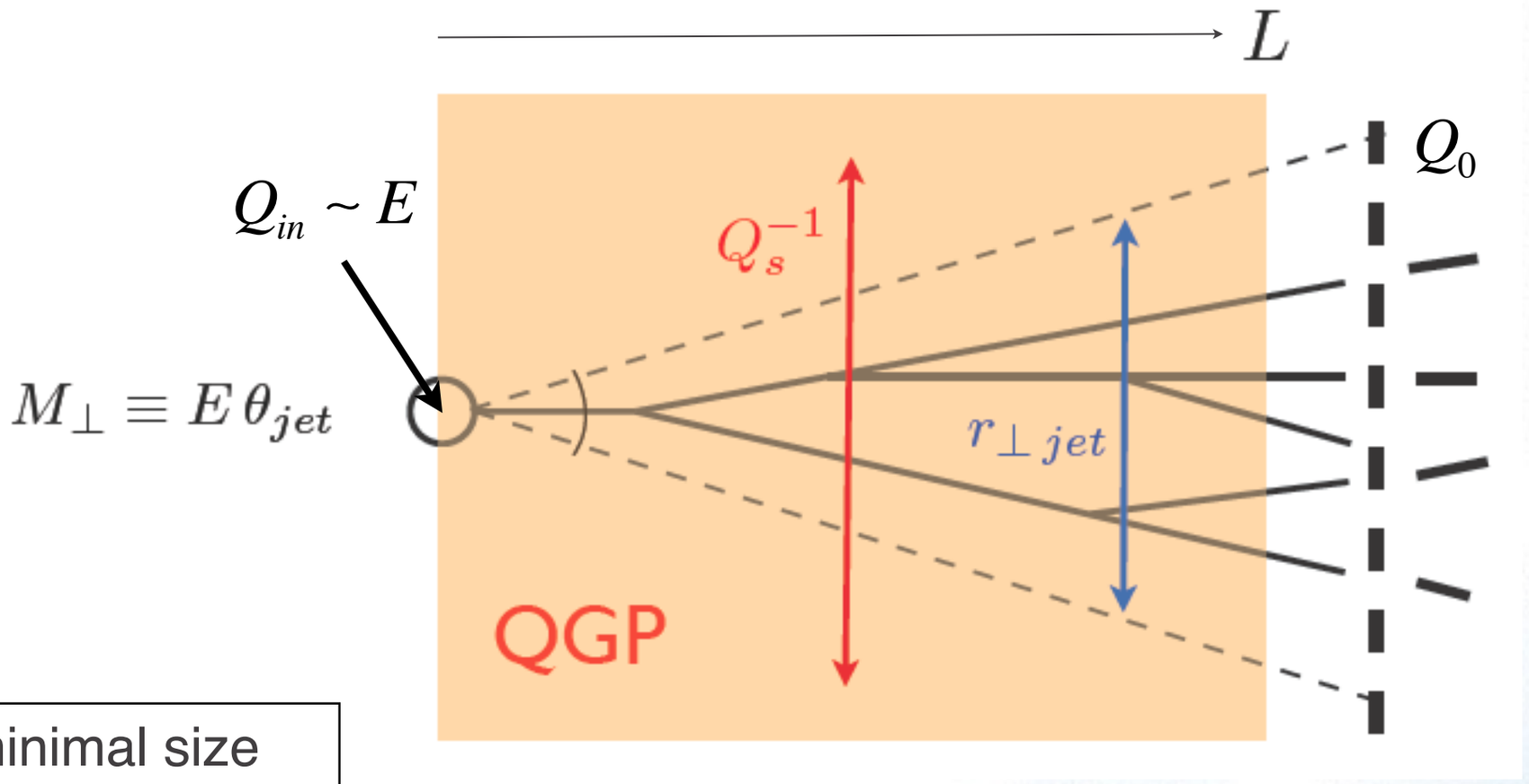




Di-jet energy asym.

RHIC +LHC data can discriminate between models

Why jets are a good medium probe



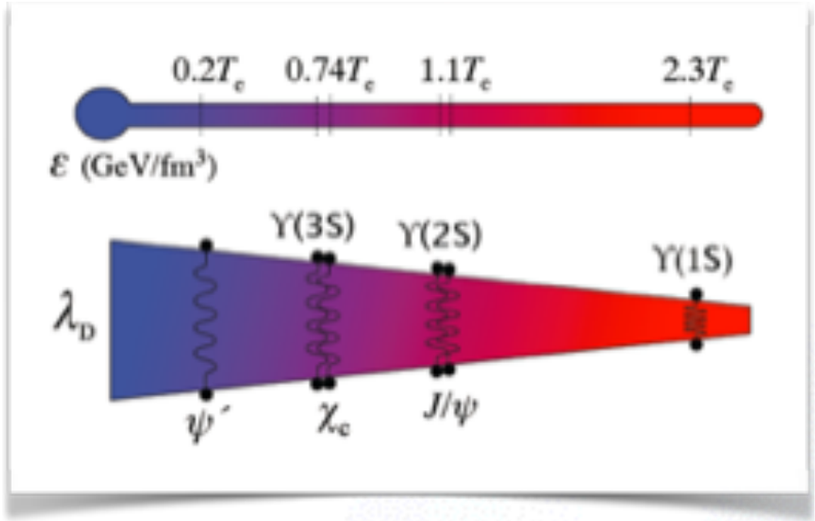
Q_s^{-1} = minimal size of probe to which the medium look opaque

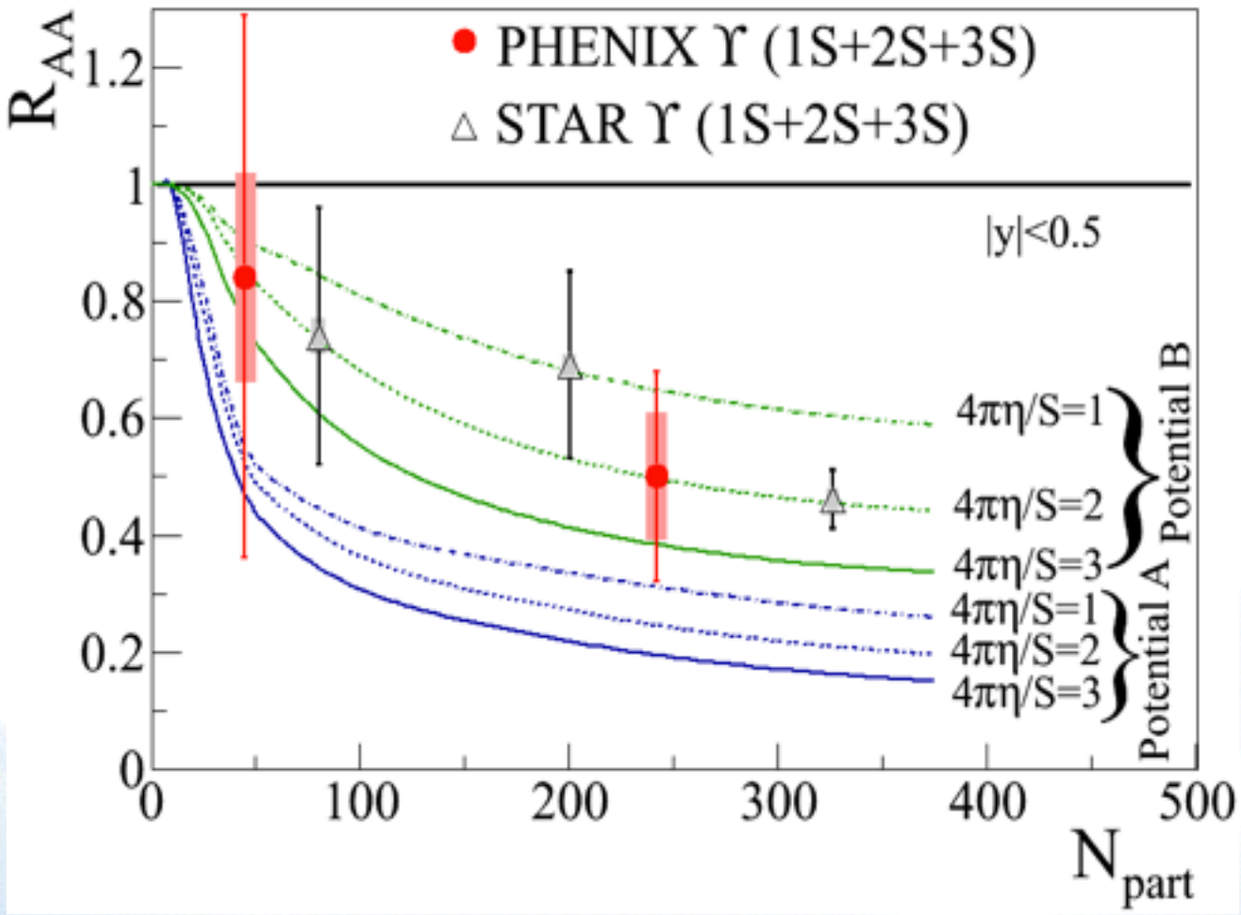
Momentum scale of medium $Q_s = \sqrt{qL} \approx m_D \sqrt{N_{\text{scatt}}}$

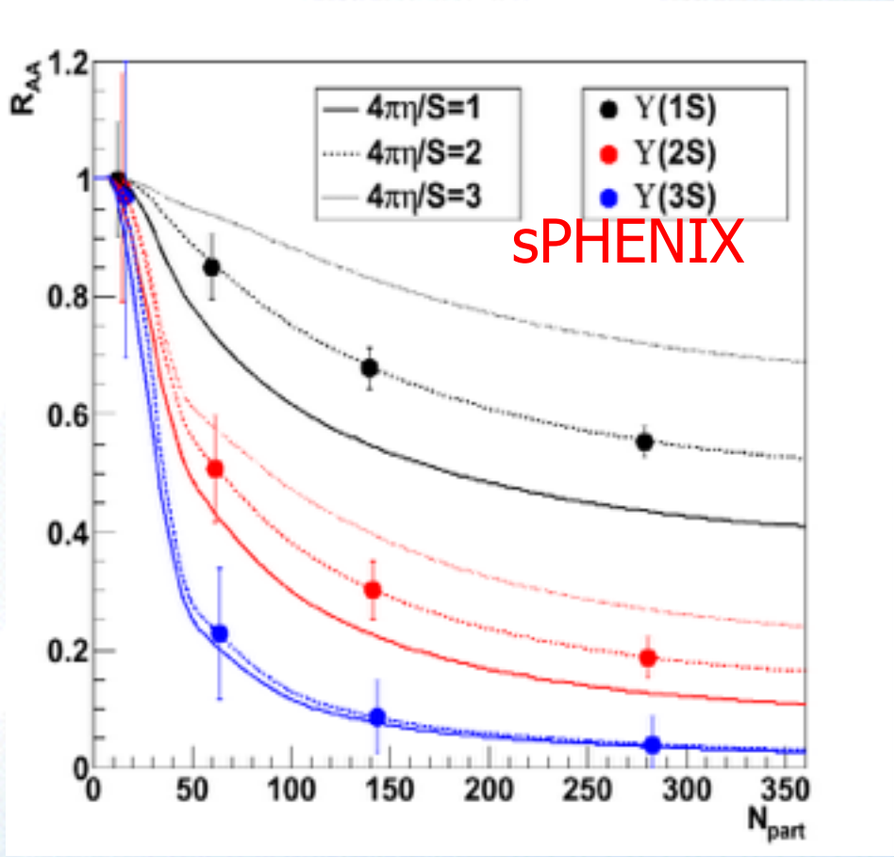
Transverse size of jet $r_{\perp\,\text{jet}} = \theta_{\text{jet}} L$

Upsilon measurements

- Wide range of Bohr radii of quarkonium states:
  - Ψ' 0.88 fm → Υ(1s) 0.23 fm
- Should lead to sequential melting (from Debye screening)



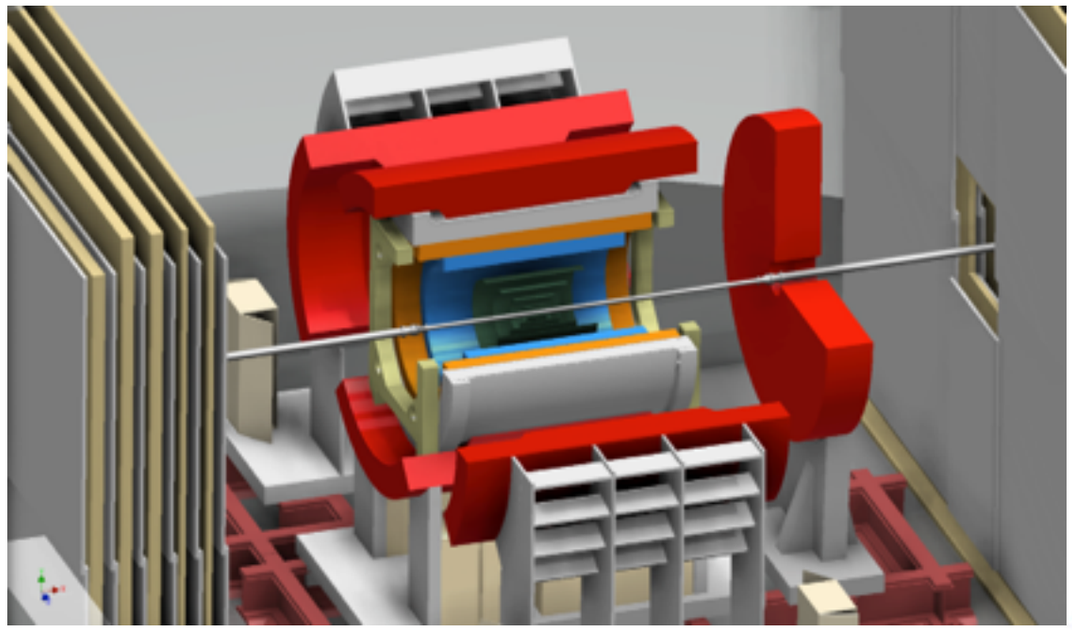




Status of

sPHENIX Project

The sPHENIX Project



- sPHENIX is a major upgrade to PHENIX. It is a new, large-acceptance, high-rate detector for HI physics to be built in the PHENIX hall.

- sPHENIX will be optimized to measure jet and heavy quark physics by incorporating a vertex tracker, full EM and Hadronic calorimetry coverage at $|\eta| < 1.1$, in a 1.5 T solenoidal magnetic field.

- It will utilize most of the infrastructure already existing in the PHENIX detector complex and the SC-magnet previously used by the BaBar experiment at SLAC.

sPHENIX Physics Plan

Two years of physics running 2021 and 2022 with 30-cryo week runs (or 3 years with shorter runs)

20 weeks Au+Au @ 200 GeV
10+ weeks p+p @ 200 GeV [comparable statistics]
10+ weeks p+Au @ 200 GeV [comparable physics statistics]

sPHENIX maintains the very high PHENIX DAQ rate
sPHENIX maintains fast detector capability – no pile up problems

In 20 weeks with current RHIC performance and PHENIX live time, sPHENIX will be able to record 50 billion Au+Au minimum bias events (no trigger bias) within |z| < 10 cm [optimal for silicon tracking]

These are recorded, not sampled (!) events, enabling a complete range of differential jet measurements and centrality selections without trigger biases.

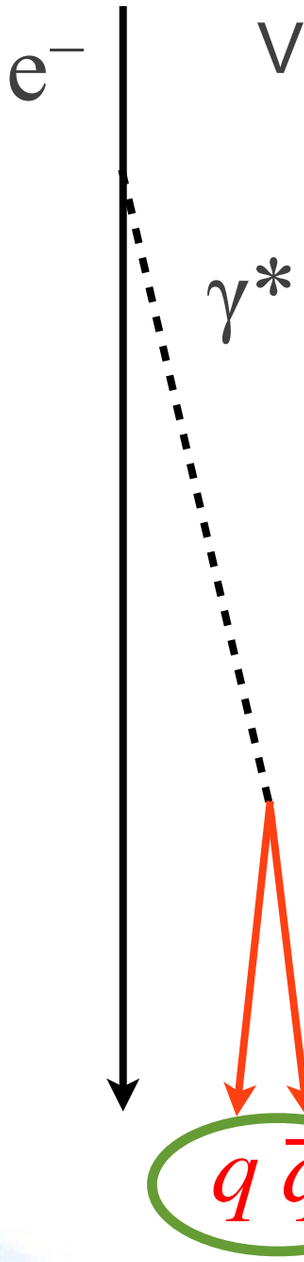
sPHENIX Status

- sPHENIX MIE proposal was submitted to DOE in Oct 2013.
- A sPHENIX science review was held at BNL in June 2013. The review was positive, but requested additional simulations, especially for b-tagged jets.
- BNL has taken ownership of the BaBar magnet; preparations for transfer from SLAC to BNL are close to complete.
- A sPHENIX Project Management Team has been formed, led by Ed O'Brien.
- A sPHENIX Project Management Group (PMG) has been formed, led by Jon Kotcher, which meets bi-weekly and advises the ALD.
- Cost review capable design and project documents are in preparation targeting a cost review in Spring 2015.

Long term plans & transition to EIC

EIC: A color dipole microscope

Free color charges (e.g. quarks) do not exist, but **color dipoles** do!
Virtual photons are an excellent source of color dipoles.



Color dipoles "see" gluons

Two resolution scales:

- momentum k (longitudinal)
- virtuality Q (transverse)

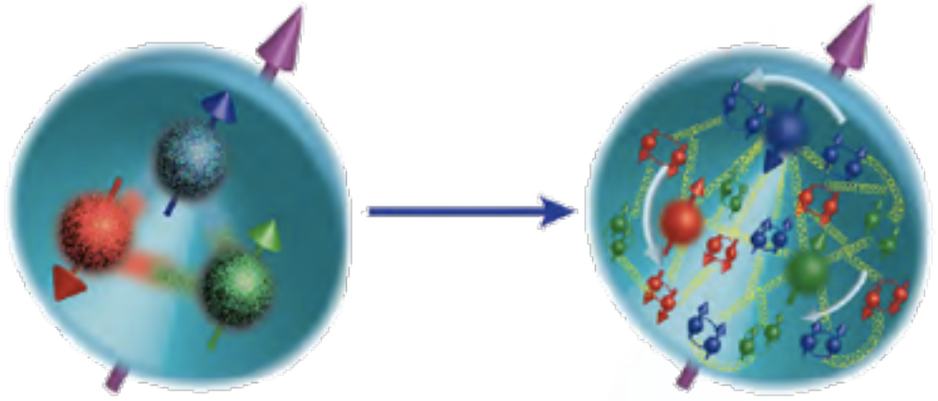
⇒ More powerful than an optical microscope!

HERA was the 1st generation color dipole microscope, with limited intensity and no polarization.

EIC will be a 2nd generation color dipole microscope, **>100-fold intensity** and **polarization**!

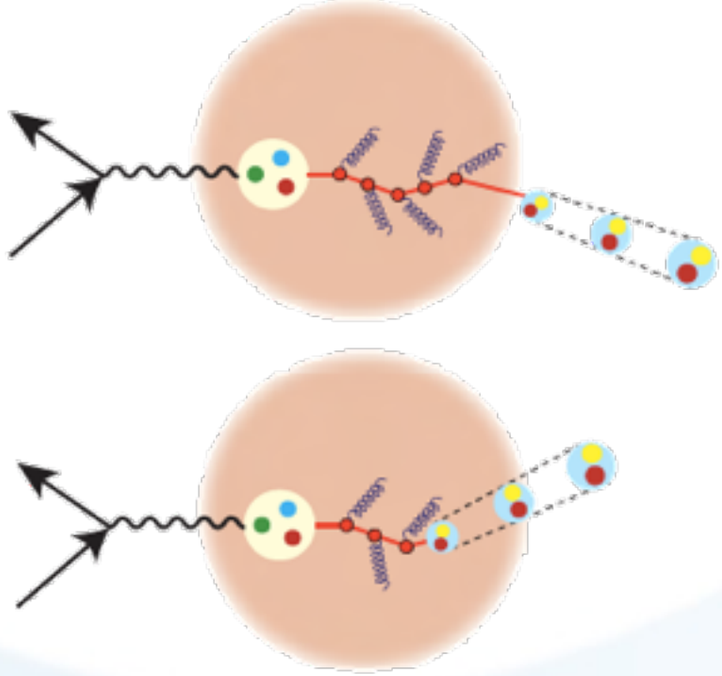
The EIC: A QCD Laboratory

Gluon structure of the proton:
How is the proton's mass generated and what carries its spin?

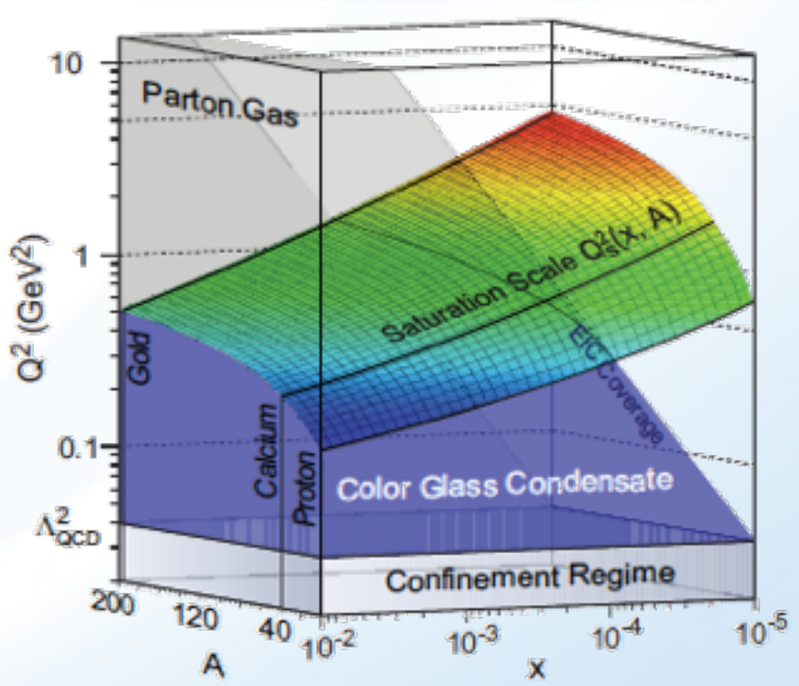


Today's proton Proton @ EIC

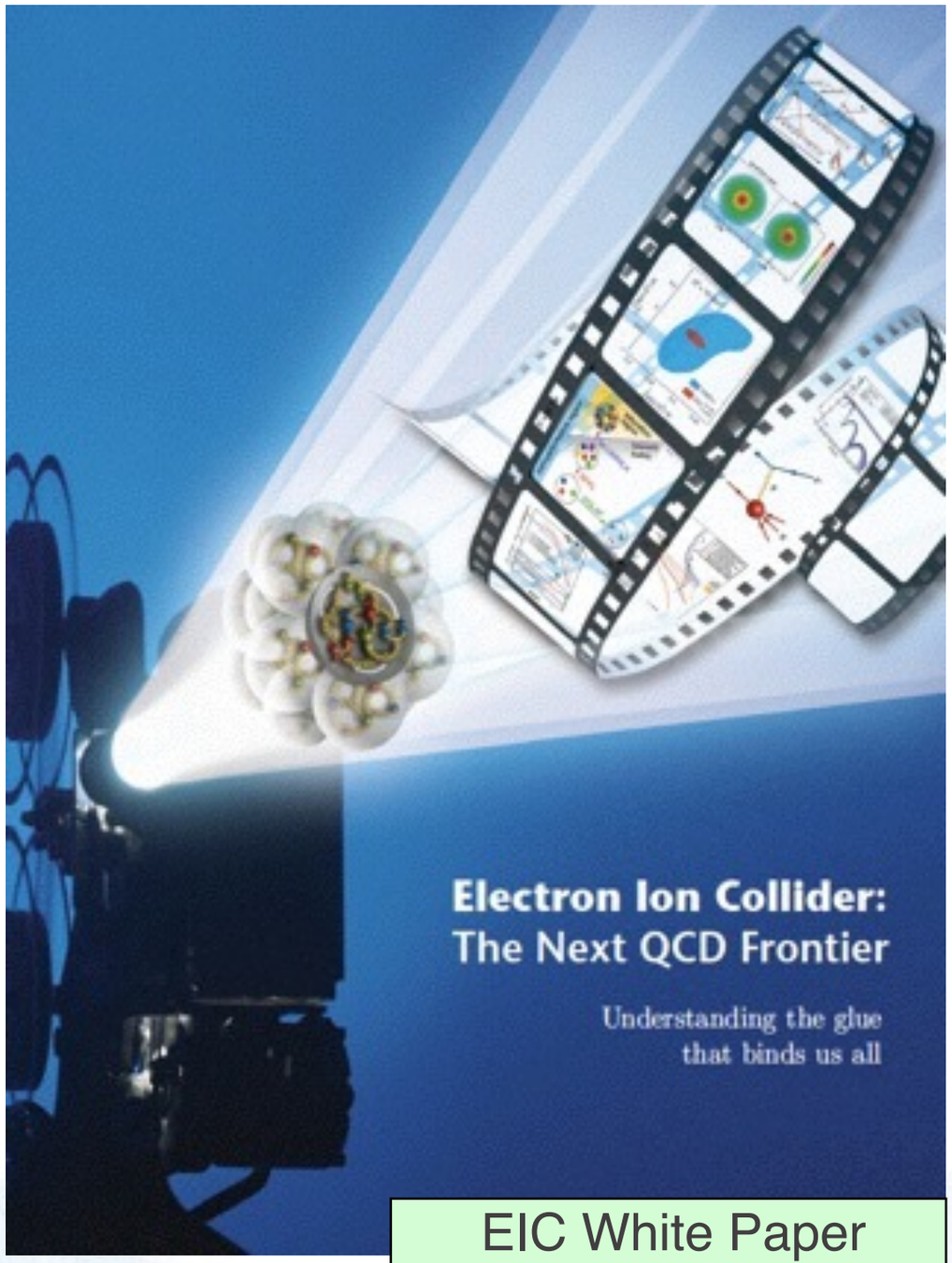
How do confined hadrons emerge from isolated quarks?



High density phase of cold gluon matter

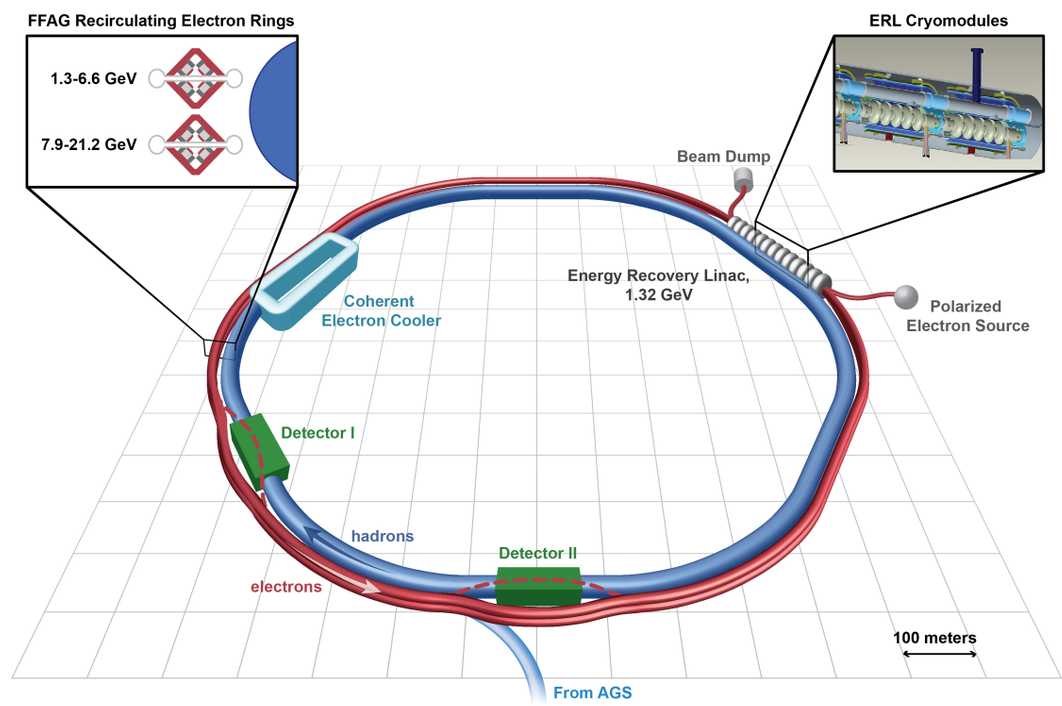


EIC/eRHIC Reports



EIC White Paper
(arXiv:1212.1701)
to be updated soon

eRHIC Design Study
An Electron-Ion Collider at BNL

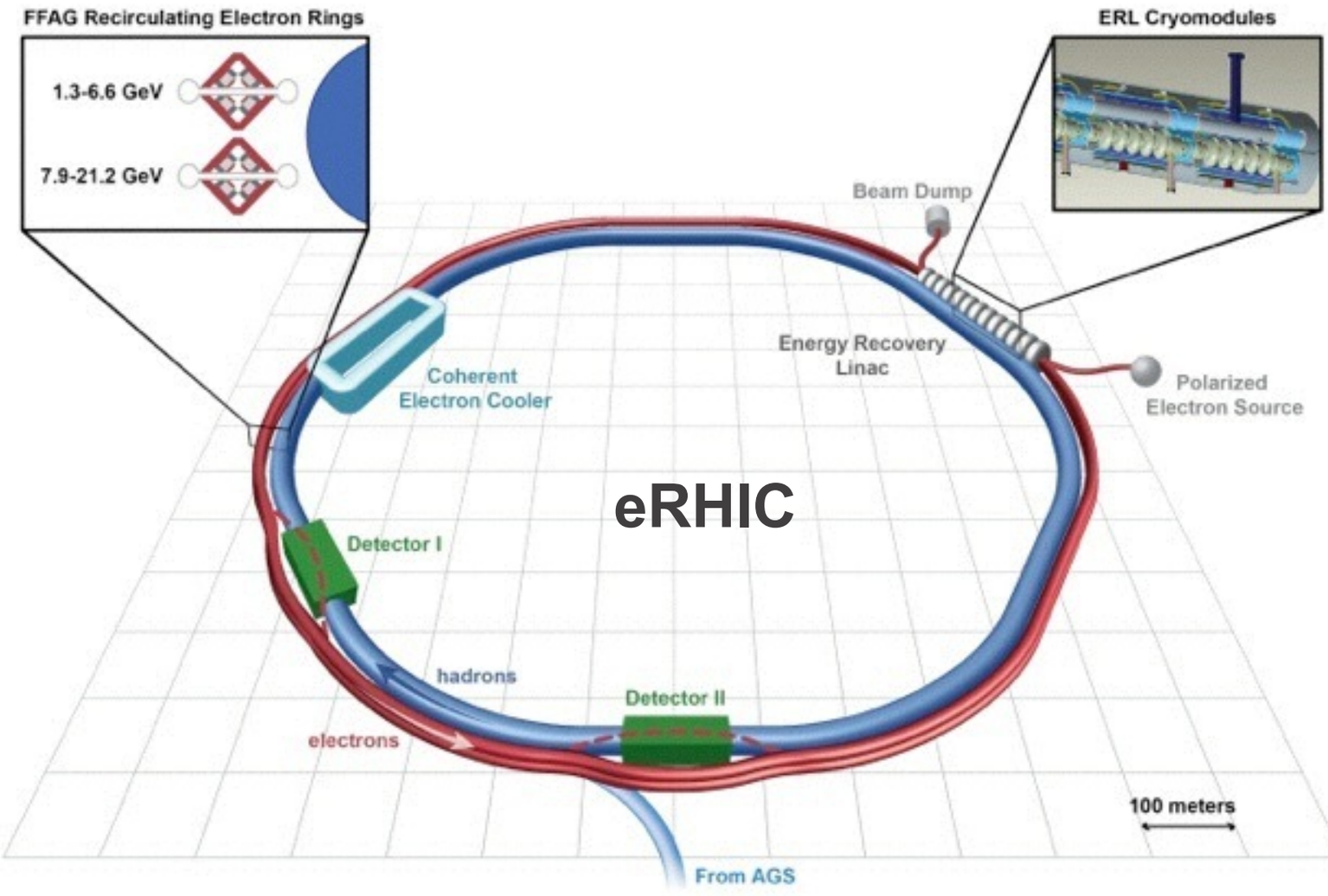


September 2014

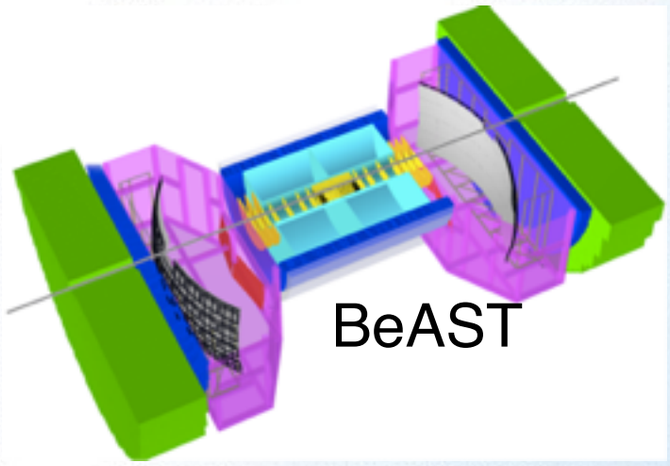
eRHIC Design

eRHIC ERL + FFAG ring design @ $10^{33}/cm^2s$

15.9 GeV e^- + 255 GeV p or 100 GeV/u Au.



Detector Options



When completed, eRHIC will be the most advanced and energy efficient accelerator in the world

The eRHIC Concept

- eRHIC will be a unique, world leading accelerator facility combining several innovative concepts:
  - World's first linac-ring collider
  - 99.8% efficient energy recovery linac (ERL)
  - FFAG arcs each propagating beams with multiple energies
  - Low cost permanent magnets for the recirculating arcs
  - Coherent e-cooling (CeC) for record high beam brightness
  - "Crab" crossings for high luminosity interaction regions
- eRHIC is a cost effective realization of an EIC.
- eRHIC can cover the whole science program outlined in the EIC white paper from Day 1.
- eRHIC can be upgraded in steps to 10^{35} $cm^{-2}s^{-1}$ luminosity.
- Upgraded RHIC detectors could serve as powerful, cost effective EIC detectors at Day 1.

Exp. Community Lab Support Synergies

Collaboration realignment

Structure of the RHIC community after 2016:

- Cross-collaboration participation
  - Collaboration By-Laws allow for membership in PHENIX and STAR
  - PHENIX members joining STAR for the BES-II
  - STAR members contributing to construction of sPHENIX
- Enduring experiment-theory collaborations
  - Jet modification in QGP (JET Collaboration)
  - Bulk transport and observables for BES-II (LBNL Workshop)
  - Heavy quark transport and quarkonium phenomenology (INT program)
- How can the existing RHIC users community and a nascent EIC users community coexist and benefit from each other?
  - How would STAR and PHENIX collaborations evolve into open eRHIC collaborations around upgraded RHIC detectors?

Laboratory Support

BNL supports the RHIC S&T Program in multiple ways:

- 10-year power contract (NYS) at ~$60/MWh
  - Power cost may grow with start of NSLS II operations
- 3-year building consolidation plan to reduce footprint and vacate old, inefficient buildings
- LDRD
- Instrumentation Division
  - Polarimetry
  - Detector/electronics development

Work for Others - Synergies

- BNL Linear Isotope Producer (BLIP)
  - Proton Linac runs in parallel with RHIC run schedule
- NASA Space Radiation Laboratory (NSRL)
  - Proton Linac runs in parallel with RHIC run schedule
- Ion Beam Therapy
  - iRCMS Crada with BEST Medical
  - Rapid cycling synchrotron for production of ^{12}C therapy
  - Compact FFAG gantries
- Accelerator S&T Applications Workshop

Response to Recommendations
2011 RHIC S&T Review

2011 S&T review recommendations I

- Generate a concise report that articulates the status of polarimetry capabilities, which evaluates remaining risks and challenges, and identifies needed resources.
  - *Report submitted in December 2011*
- RHIC management should identify in detail where the running efficiencies are lost and develop a plan articulating how they will address these inefficiencies, with a goal of reaching running efficiencies of at least 85%.
  - *Report submitted in December 2011*
- Review and clarify the roles and responsibilities of RHIC and the detector collaborations for maintaining and operating detectors and their upgrades and resolve the appropriate funding mechanisms. Conduct a bottom-up exercise of the current and anticipated experimental support needs for RHIC, explaining and justifying the staffing levels.
  - *Report submitted in January 2012*

2011 S&T review recommendations II

- Prepare a commissioning plan for the eLens project, which describes commissioning personnel and activities, and durations of tasks and goals in the context of the overall RHIC operations. Present the plan at the next DOE eLens review.
  - *Both e-lenses are installed and pre-commissioned with Au beam*
- The nuclear theory group should identify a small number of quantities for important experimental observables and consider focusing some of its efforts on producing quantitative predictions that can be used for precise theory-data comparisons. These results should be presented at the next S&T review.
  - *See presentation by R. Venugopalan*
- BNL management should address user concerns regarding housing upfront and openly so that users know what to expect; a process needs to be developed lab-wide that gives users access to on-site housing. Report progress to DOE at the bi-weekly conference calls.
  - *See report from UEC chair*

Response to Recommendations 2013 RHIC Operations Review

2013 Ops review recommendations

- Formalize tracking and reporting of a reasonable set of activity-based analytical metrics representing aspects of RHIC operations. Provide to DOE/NP a draft report by December 2013.
  - *Sample analysis (Vacuum Group) submitted in January 2014; analysis of other operations groups is in progress*
- Use the to-be-established management process to document a rationale for program optimization to DOE/NP by December 2013.
  - Report submitted in December 2013
- Work with the laboratory to develop a plan to consolidate the buildings associated with RHIC. Report plan to DOE/BHSO and DOE/NP by end of October 2013.
  - Building consolidation plan submitted in October 2013